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Apple Aphids in Ohio

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AGRICULTURAL EXPERIMENT STATION
Wooster, Ohio

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IDENTIFICATION TABLE FOR APPLE APHIDS

Apple aphids in order of their seasonal appearance	Eggs* Place of overwintering	Time of appearance of lice on apple	Description of aphids	Injury	Migration and hosts
Apple-grain Aphis	On small branches, fruit spurs, and slow growing terminals. Placed about bud scars, rough areas, or wounds.	First aphids to appear in spring. Usually abundant on swollen fruit buds.	**Young.**—Dark green in color. **Mature forms.** — Light green with a dark green stripe down the middle of the back and cross bars of same color.	Feeds on fruit buds, leaves, and opening blossoms. Causes no visible injury.	Leaves apple about time of petal-fall spray, going to grains and grasses where it spends the summer.
Rosy Apple Aphis	On somewhat larger branches than above species. May also be placed on trunk of tree.	On buds about 7 days later than apple-grain aphis. Usually not abundant till petal fall or later.	**Young.**—Very dark purple, covered lightly with grayish dust. **Mature forms.**—Mostly slate colored with some rosy or pink individuals.	Tightly curls foliage about fruits. Gnarled and dwarfed fruit remaining in clusters thruout the summer.	Leaves apple from middle of June to July 1. Spends summer on different plantains.
Green Apple Aphis	Eggs on those water sprouts and terminals that have grown till late in autumn.	On buds as first leaves are unfolding. Greatest abundance in orchard occurs from mid June to August 1. Lice on growing terminals.	Lice are solid green in color. In summer on old foliage some yellowish forms may be seen.	Curls foliage of terminals to some extent. Covers foliage and fruits with honeydew, on which grows a black fungus that discolors fruit. May cause some dwarfing of fruit.	Migration from apple to apple during late May and summer months. Migration to secondary hosts in late May and early June.
Woolly Apple Aphis	Eggs on the bark of branches and trunk of elm. Also living lice overwinter on roots of apple.	Curled leaves on elm may be noted in May. First comes to apple in early June; from roots of apple about the same time.	Purplish-red lice covered by a bluish-white woolly excretion. Colonies appear as woolly areas on branches or roots of the tree, at base of leaf stem, or about wounds.	Causes warty gall-like formations on branches. This was formerly called aerial crown gall. Causes swollen galls on the roots.	An annual migration occurs from elm to apple and return, but aphids may also live on the roots of apple for several years without migrating.

*The eggs of all aphids are small, glistening black in color, and oval in shape. They can be seen with the naked eye but are so small that it is a difficult matter to count them without a magnifying glass. The eggs of different aphids cannot be differentiated.

APPLE APHIDS IN OHIO

C. R. CUTRIGHT

Popular Section

INTRODUCTION

During the growing season, the aphids or plant lice that attack the apple are called to the attention of the grower with great frequency. In spring, the swelling buds may be almost covered with them; while later, the foliage about the blossoms may be curled and distorted. In summer, growing terminals or water sprouts may be crowded by thousands of lice. In autumn, the lice are still present on the foliage and gnarled fruits give evidence of past attack. At certain times they may seem to have vanished entirely but within a few weeks they reappear in countless numbers. Such seemingly unreasonable behavior frequently arouses in the mind of the grower considerable concern as well as a great curiosity regarding these insects.

APHIDS[1] IN GENERAL

All aphids, no matter on what plants they may feed, have certain points in common. Thus the life histories of the different species resemble each other to such an extent that a general life history may be written which, in its major features, fits all species. Such an account follows: Plant lice in autumn deposit overwintering eggs on one or more plants that are known as the primary hosts. The eggs hatch in spring and the aphids so produced are wingless forms known as stem mothers. These produce living young without the intervention of males. These young, after becoming mature, reproduce as did their mothers and may or may not have developed wings. The winged forms fly either to new host plants of the same species or plants of a different species. These later are known as secondary hosts and are the ones that usually support the lice during the summer months. In time almost all of the lice on the primary host develop wings and fly to the secondary. Aphids develop and reproduce so rapidly that as

[1]The term aphis, technically speaking, should be used only in reference to a plant louse that belongs to the genus *Aphis*. Species falling in other genera should be called aphids, singular aphid. However, general usage seems to sanction the term aphis and it is frequently used interchangeably with aphid. In this paper aphis is used to mean one, or members of one, species that is under discussion. Aphids will refer to two or more species that are being discussed together.

many as 15 or 20 generations may occur during a growing season. In autumn, winged forms develop on the secondary hosts, which return to the primary. Here they deposit young lice that develop into true sexual forms in that the female must be fertilized in order to produce hatchable eggs. These eggs overwinter as recorded above. They are always small but can be easily seen with the naked eye; they are oval in shape and a bright glistening black in color.

General control of all aphids.—Aphids are sucking insects and so must be attacked by the use of contact insecticides. Such materials are oils, of which Kerosene emulsion, lubricating oil emulsions, and miscible oils are examples; derris extracts, of which the most common commercial preparation is Derrisol; pyrethrum sprays such as Evergreen, M. P., and Red Arrow; tobacco extracts including nicotine sulphate, free nicotine, and nicotine products of other types. Some of the above materials may be prepared at home but it is usually far more convenient and dependable to buy and use standard commercial products. Sprays will be further discussed in relation to each species of aphis.

No matter what material is used against plant lice, it is absolutely necessary to get from 99 to 100% mortality if the control is to be considered effective, because of the tremendous rapidity with which aphids reproduce. For example, if an aphis-infested tree or plant is sprayed and 95% of the lice killed, five aphids out of each hundred are left alive. If these remaining lice reproduce at the rate of five young per day (This rate is slower than normal) in four days we will again have on the tree or plant as many lice as we started with. The 95% control that was obtained was therefore almost entirely wasted effort.

Natural controls.—Fortunately we do not always have to depend on insecticides to control aphids as there are many factors in nature that work against them. Among these are their predaceous enemies such as lady bird beetles, syrphid fly larvae, and many others. Parasites and diseases at times greatly decrease their numbers. Weather conditions may affect the lice directly as in the case of early or late freezes, storms, and beating rains. Indirectly the weather may influence the growth of the host plants so that they are rendered unsuitable as food for the lice. This last factor is one of great importance in the natural control of different species.

APPLE APHIDS IN OHIO

Several species of aphids are found on apple and it is the purpose of this general section to give orchardists, or other interested parties, a general picture of each aphid species and to present briefly the known facts concerning its life history, habits, and control.

The following species of apple aphids are to be found in Ohio:

The apple-grain aphis, *Rhopalosiphum prunifoliae* (Fitch)
The rosy apple aphis, *Anuraphis roseus* Baker
The green apple aphis, *Aphis pomi* De Gr.
The woolly apple aphis, *Eriosoma lanigerum* (Hausm.)
The clover aphis, *Anuraphis bakeri* (Cowen)

The last named species will not be further considered in this account as it is rarely found in Ohio and has never appeared in numbers sufficient to be considered of economic importance. Each of the other species named above will be given separate consideration from the standpoint of its life history and possible means of control.

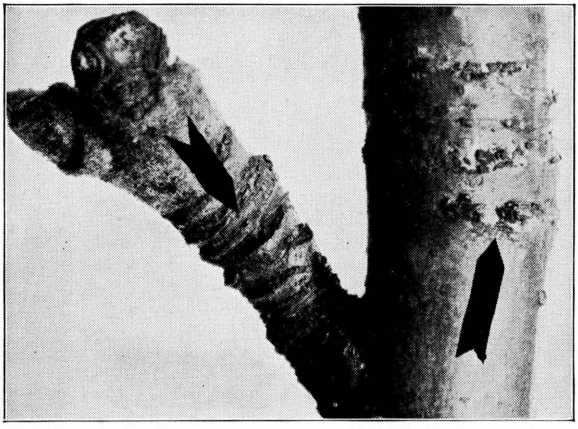

Fig. 1.—Eggs of the apple-grain aphis on fruit spur and larger branch

THE APPLE-GRAIN APHIS

This is the aphis that is so conspicuous in early spring on the swollen fruit buds of apple. The eggs of other apple aphids have not yet hatched in any number; therefore, the grower can be quite

positive as to the correct identification of this species. Later on when this aphid is to be found among the foliage about the flower buds it develops a dark green line running down the middle of its back with four or five cross lines of the same color; most of the body is a much lighter green.

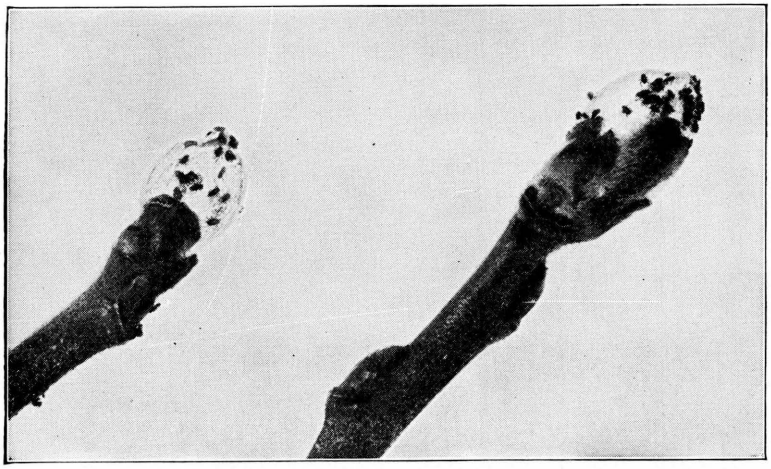

Fig. 2.—Newly hatched apple-grain aphis on swollen buds

Life history.—The winter is passed in the egg stage, on the bark of slow-growing terminals, fruit spurs, or on larger branches. The small, glistening, black eggs are usually placed about buds or other rough areas on the bark. They hatch earlier in the spring than the eggs of other species and are practically always far more abundant. Eggs have been noticed hatching as early as March 3 at Wooster but this, of course, was due to abnormally warm weather in that particular season. In northern Ohio, the majority of hatching occurs during the first two weeks in April; while in the southern part of the State this may be expected to occur from one to two weeks earlier. The newly hatched lice do not withstand cold weather well and numerous individuals will be found dead after periods in which the temperature falls below 22° F. With normal spring temperatures prevailing, the young lice, or stem mothers as they are called, grow and become mature in about two weeks. In one or two days after becoming mature the stem mothers start to reproduce, this process being parthenogenetic, that is, without the intervention of the males; also instead of laying eggs the stem mothers bear living young. The number of young to which each stem mother may give birth varies greatly, but according to several

authorities it averages from 75 to 100 per individual. During their period of growth most of the young of the second generation develop wing pads and at maturity become fully winged. The few aphids that do not become winged produce a third generation, all of which develop wings. The first of the winged forms leave the

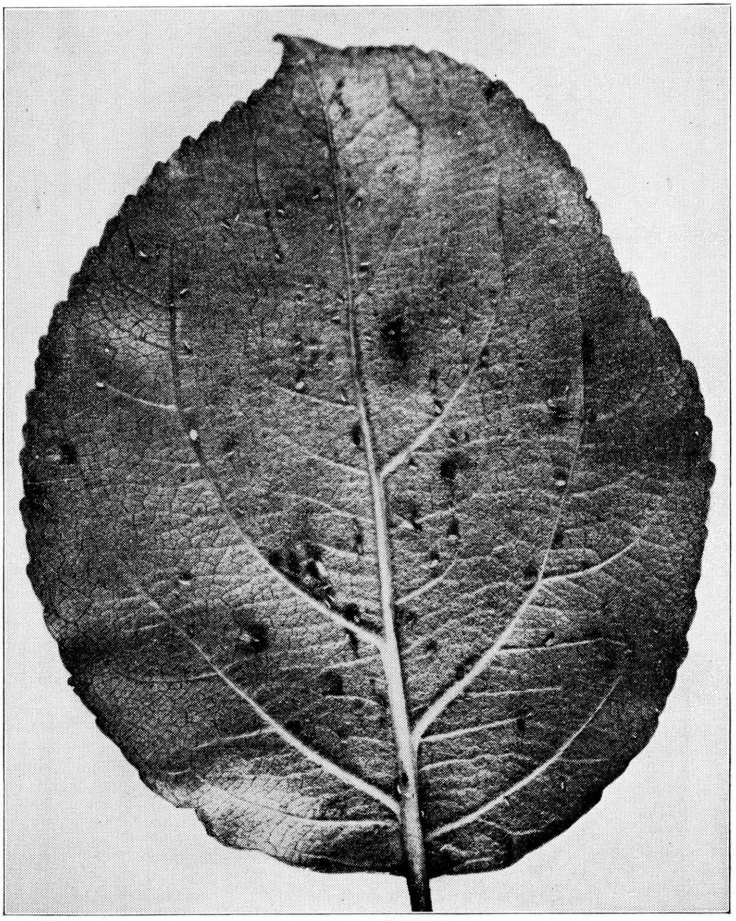

Fig. 3.—Fall migrants and egg laying females of the apple-grain aphis on underside of apple leaf

apple as the petals start to fall and migration continues for about two weeks, at the end of which time none of the apple-grain aphids are to be found on the trees. The plants to which the migrants fly are different cereals and grasses, and on these the lice spend the summer months.

During the autumn months winged forms develop on the grains and grasses and later return to the apple. The first of these may appear on apple in early September, and arrivals continue into November. After establishing themselves on the foliage, they give birth to young lice that develop into true female forms. Winged males that have developed on cereals and grasses now fly to apple and fertilize the females, after which the overwintering eggs are deposited as has already been described. The bulk of egg laying occurs during late October and early November.

Control.—No control for this aphid is needed as it is not sufficiently injurious to make aphicidal sprays or other measures practical. It does not attack the fruit and its feeding on the foliage causes little if any distortion. However, one can always remember that sprays used against the other species will affect the apple-grain aphid if it is present on the trees. For example, a delayed dormant spray applied against the rosy apple aphis will destroy large numbers of the apple-grain species.

THE ROSY APPLE APHIS

Life history.—Authorities are agreed that the females of the rosy aphid deposit their eggs under bark and about rough areas on somewhat larger branches so that they are not as readily noticed as are the eggs of the apple-grain aphid. Eggs may also be deposited on the trunk of the tree. The females of the rosy aphid are far less abundant in autumn than those of other species and so the eggs are far less numerous. The writer doubts if the eggs of this species in Ohio ever amount to one per cent of the total of all aphid eggs on apple. The majority of hatching occurs about a week after that of the apple-grain aphis, and if examinations of buds are made at this time a few of the young lice may be found. Due to the later hatching they are smaller at this time than the other lice; they are dark purple in color and appear as though a white powder had been sprinkled lightly over the body. Usually several hundred

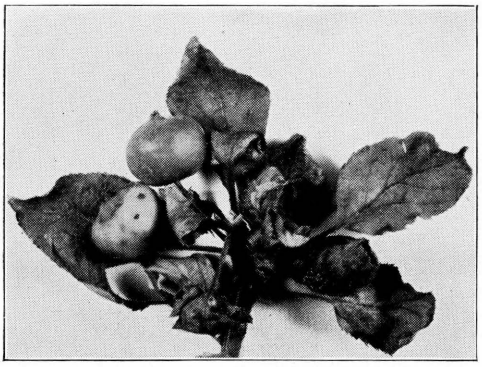

Fig. 4.—Injury by the rosy aphis to apple fruits and foliage

of the other green aphids can be counted for every one of the rosy aphids found. As they grow, practically all become slate colored. They move to the young leaves as soon as these unfold and there produce the tightly curled and distorted foliage that is so characteristic of injury by this species. The stem mothers become mature in about two weeks as do those of the apple-grain aphis, but are able to reproduce almost twice as rapidly as the latter. Also the species remain on the apple for one or two more generations before migrating. Thus, great numbers are occasionally found on trees during the month of June. During late June and early July the aphids of the third and fourth generations develop wings and leave the apple, going to different plantains where they spend the summer. A few colonies may be found on apple even in August but usually the trees are free from this species shortly after the first of July. The apple fruits are attacked by lice of the third and fourth generations when crowding occurs on infested foliage. In their search for new food the fruits are found and feeding by even a few lice is sufficient to cause the gnarling and permanent dwarfing of the young apples. In autumn winged forms from plantains fly back to the apple and produce true females that later deposit the overwintering eggs. The male aphids develop on plantain and later fly to apple where they find and fertilize the females before egg laying is started.

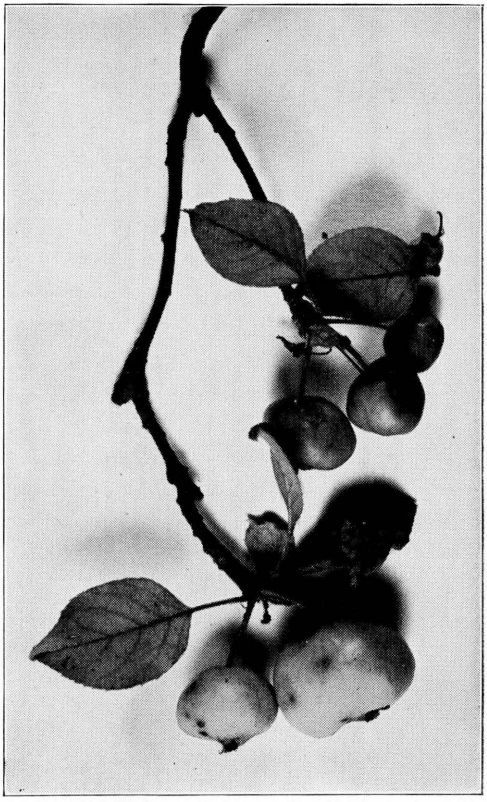

Fig. 5.—Apple fruits injured by the rosy aphis

Control.—The rosy apple aphis causes serious injury to apple when it is abundant and is potentially our most dangerous species.

In New York and other states, instances frequently have been recorded in which trees have lost over 50% of their crop through attack by this species. In Ohio it is fortunately not as abundant as in some other states; hence instances of such severe injury are quite rare. In some orchards, however, it is sufficiently abundant in certain years to cause the growers considerable concern. The habit of appearing in great numbers one year and of being almost entirely absent for one, two, or more years following is common to all aphids and, if anything, it seems to be accentuated in this species. This habit keeps the grower guessing as he may apply an expensive spray and the aphid then fails to appear even on unsprayed trees. Thus the cost of including aphicides in the spraying program over a period of three or four years may amount to more than the loss from damaged fruit in one year in which the rosy aphis is abundant. It has been proven that there are sprays which, if applied to the trees at a certain time of the year and with a reasonable degree of thoroughness, will bring about a definite commercial control of this species. Therefore, the proposition of using these sprays simply amounts to a matter of insurance and each grower must determine for himself whether or not such insurance is too expensive.

The spray that has always given us best results in Ohio is applied during the delayed dormant period and consists of:

Liquid Lime-Sulfur	12½	gal.
Nicotine Sulphate	¾	pt.
Water	87½	gal.
or		
Dry Lime-Sulfur	30	lb.
Nicotine Sulphate	¾	pt.
Water	100	gal.

Almost paralleling the above sprays in efficiency are different miscible oils and oil emulsions. Miscible oils applied during the periods when buds are swelling and at strengths recommended by the manufacturers have given in almost every instance a commercial control. Oil emulsions applied when the buds are even more enlarged have likewise given good commercial control.

The late dormant and the delayed dormant periods are the ones in which any of the above sprays must be applied to control the rosy aphis. Even in the pink spray, or late pre-bloom spray, almost no results can be secured as the lice are so thoroly protected by the curled foliage. Nicotine should never be used in the pink, calyx, or two-weeks sprays with the idea of controlling the rosy aphis, as numerous experiments and observations have shown that the

nicotine is simply wasted. Nicotine is the insurance feature of the early-season lime-sulfur sprays and should be used with that idea in mind; the lime-sulfur part of the spray performs various other functions. In Ohio the oil sprays are used principally against scale and red mite so that the control of aphids may be considered as an additional feature of such a spray.

Fruit and foliage that are in dense shade are most frequently attacked and for this reason a system of pruning has been advocated in which the top of the tree is opened up and sunlight admitted. There is no direct experimental evidence on this point, though numerous observations would tend to support such a practice.

All varieties of apples are subject to attack but, in Ohio, Maiden Blush and King David seem especially susceptible to injury. Jonathan is also heavily infested at times, and under conditions of extreme aphid abundance no variety escapes.

THE GREEN APPLE APHIS

The green apple aphis is by far the most abundant species in Ohio and, as such, attracts more attention and causes more injury than any of the other plant lice on apple. This is the species that is so abundant during June and July on young trees, water sprouts, and vigorous growing terminals. It curls the foliage and covers it with honey dew on which grows a black fungus that smuts both fruit and leaves and causes considerable discoloration especially of early apples.

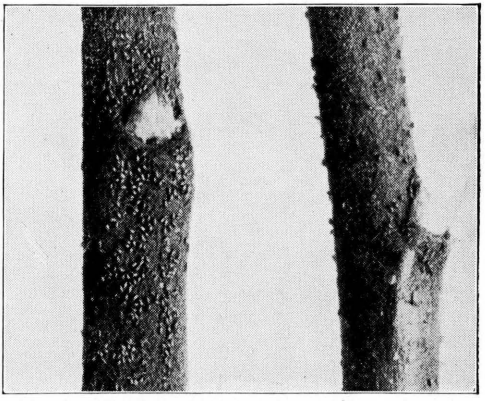

Fig. 6.—Eggs of the green apple aphis on water sprouts

Life history.—The insect overwinters as a small shiny black egg on water sprouts or terminals that have grown till late in the season. The leaves about the fruit buds have started to unfold when the first eggs hatch, and thus offer favorable food to the young aphids. These become mature in a little over two weeks and then start to reproduce. The reproductive period lasts nearly a month and each female will average about 50

young. In the case of the other aphids discussed, the winged forms do not appear in numbers until later generations. However, in the case of the green apple aphis the great majority of this generation become winged and fly at once to new food. Some of the winged lice fly to any of a large group of plants which serve as summer hosts but most seem to fly to other apple trees where they settle on new growth and start new colonies. The migration to apple may start as early as the middle of May, in Wooster, and reaches its height by June 1. The migrants will reproduce to any extent only

Fig. 7.—Center of an apple tree with large number of water sprouts heavily infested with green apple aphis. Note drooping leaves.

on new and succulent growth. If they alight on old foliage they soon leave it and continue the search for suitable food. During the summer months numerous generations occur on apple and these follow each other in rapid succession until the slowing down of growth in the trees creates unfavorable food conditions. When such conditions occur a much greater time is required for a generation to complete its development. Migration by winged forms from one tree to another occurs during almost the entire summer. In August and during the autumn months the species is found almost

altogether on water sprouts or terminals of young trees that are still growing, and it is in such locations that the sexual forms are developed and the overwintering eggs deposited.

Control.—In discussing the two preceding species of aphids it has been shown how their control depends largely on the application of an aphicidal spray just before the leaves unfold. From this we might be led to believe that a similar spray would be the first requirement in the control of the green apple aphis. This, however, is not the case since an infestation of rosy or apple-grain aphids arises from the eggs that are already on the tree; while an infestation of green aphis comes from the migrants of the first generation that settle on apple.

The application of an early spray will be just as effective on the green aphis that are on the tree at that time as against the other aphis species, but green aphis migrants come from untreated trees, often at considerable distances, and also from other hosts such as pear, spirea, Japanese quince, and others. Therefore, a late dormant or delayed dormant spray is not recommended for control of this species. An exception exists in the case of an orchard where extensive top working is under way and the removal of all water sprouts is not advisable; such trees should receive an early spray such as the sprays recommended for the control of the rosy aphis.

The recommended practice is to spray with the following formula when the aphids appear on the trees in June, if the colonies are abundant and the terminals are still growing vigorously:

Nicotine Sulphate (Black Leaf 40)	¾ pt.
Miscible oil or oil emulsion	¾ gal.
Water	100 gal.

In the case of the oil emulsion the amount may be increased to one gallon without danger of burning. In place of oil, soap of any kind may be substituted at the rate of 4 pounds per hundred gallons. A few field trials of "Penetrol", a new type oil spray, used at ½ of one per cent, plus nicotine sulphate at 1-4000 or ⅕ pint to 100 gallons of water, have shown that this combination has decided promise. Experiments with it have reached the point where it can be recommended to growers for independent trial. When it is desired to combine nicotine with lime-sulfur or lime-sulfur-arsenate sprays it may be used at the rate of 1 pint per 100 gallons of the spray and the oil or soap must not be used. At times such a combined spray may be used to advantage, for instance, when aphids are abundant at the time of the 2-3- or 6-weeks' spray.

At times it is unnecessary to spray, as the infestation naturally declines. At other times, so favorable are conditions to the aphids that even the best spraying fails to hold the insects in check for more than a week. In almost any instance, spraying is something of a gamble. The writer has seen numerous instances where spraying undoubtedly benefited the crop and others in which no visible improvement could be noted. The secret of successful aphis spraying lies in the thorough application of large amounts of the spray. If the grower is not willing to do this, he might as well not spray at all as his efforts are almost sure to be wasted.

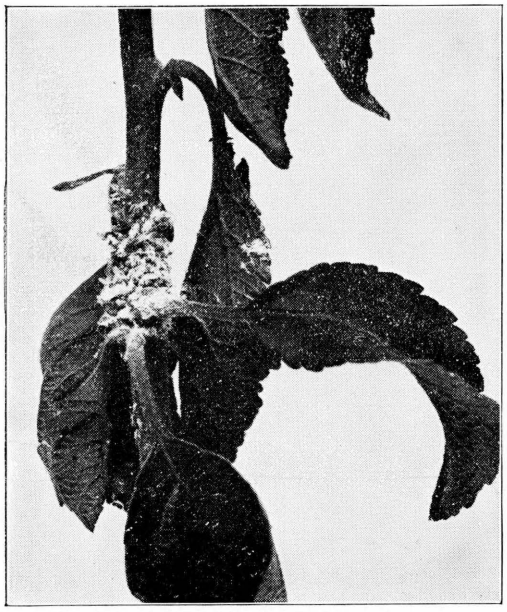

Fig. 8.—Colony of the woolly apple aphis at the base of leaf petiole

Dusting is an effective means of control if the dust carries a sufficient amount of nicotine and is applied to the trees under the correct conditions. Such conditions are: 1, absolute calm or almost no air movement, and 2, high temperatures, averaging at least 70° F., or more if possible. The dust should contain about 3 per cent actual nicotine. Such a mixture can be obtained by incorporating nicotine sulphate at the rate of 7½ pounds in 100 pounds of hydrated lime.

Dusting or spraying from the commercial standpoint does not mean that every tree in the orchard need be treated. Frequently certain trees that are heavily infested are the only ones requiring attention. A system of this nature can be used to advantage when an infestation develops in July or August. This is because growth has started to harden, and favorable food for the aphids is decreasing in amount, thus prohibiting any great increase in numbers on other trees.

Pruning, consisting of the removal of water sprouts from the tree, is a great aid in control. Such growth should be removed

during the dormant pruning season and as soon as it appears in summer. Water sprouts if allowed to remain on the trees furnish the lice with the best of food during the entire season and finally carry the eggs over the winter. In orchards suffering from green aphis attack this type of pruning can not be neglected.

THE WOOLLY APPLE APHIS

The woolly apple aphis is a species common and generally known throughout Ohio but of late years, at least, it has caused little concern to commercial growers. It is still a pest of considerable importance to nursery men engaged in propagating the apple. The species is best identified by the appearance of the colony which consists of a number of brownish to purple lice covered by an abundant bluish-white woolly excretion. The colony above ground is usually located at the base of a leaf petiole, or about wounds or pruning scars.

Fig. 9.—Woolly apple aphis about a wound on apple

Life history.—This insect passes the winter in two different forms; 1, as eggs on elm trees, and 2, as living individuals on the roots of apple and other closely related plants. In the spring the eggs hatch and the young lice feed upon the elm leaves which they cause to curl into a rosette. In this rosette, winged lice develop that fly to apple; in northern Ohio this flight is usually noted during the first part of June. On apple, colonies are formed in the locations noted above and from these at different times during the summer certain lice migrate to the roots. In autumn, winged forms appear in both the aerial and the root colonies and these return to elm where the sexual forms are produced and the eggs laid. Of the lice that remain on apple, those in the aerial colonies are killed by winter weather, but those on the roots live to continue reproduction the

following year. The injury done by this species consists of gall-like formations on the branches and of swollen enlargements on the roots. These are started and increase in size from year to year due to the feeding of the lice. Such galls at times form a favorable place for the attacks of various fungi.

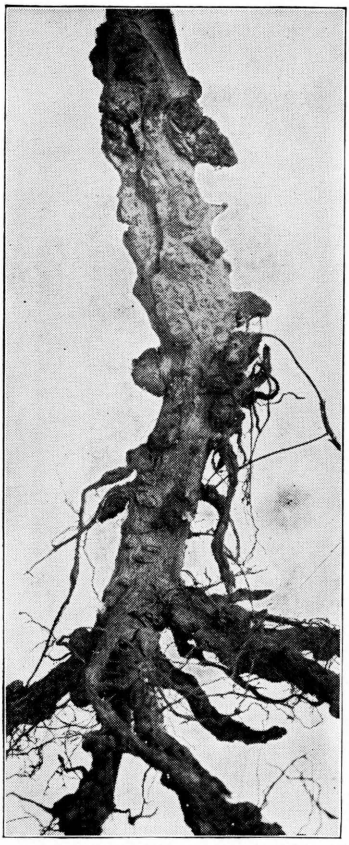

Fig. 10.—Galls on the roots of apple caused by the woolly apple aphis

Control.—The woolly apple aphis may be attacked in several ways, but once it has become established on the roots of apple it is almost impossible to eradicate it. The sucecssful control of this louse depends upon keeping the top of the tree reasonably free from aphids. The following control program usually meets all needs:

1. If possible, do not plant trees that show the aphis galls or swellings on the roots.

2. Dip in a nicotine soap solution all trees that might have living aphids on roots or tops. Trees that have been fumigated are usually free from aphids.

3. In nurseries where root grafting is practiced the roots should be treated to insure freedom from aphids. The stock should then be set at some distance from infested trees. If there are many elm trees near by, and a heavy migration to apple is noted, nursery stock may be sprayed with a nicotine-oil or nicotine-soap solution such as is recommended against the green aphis. This should be applied in early June and again about 2 weeks later. The migrants and their colonies are thus destroyed before individual lice have a chance to infest the roots.

4. If the roots of a tree in a permanent planting become infested there is probably no better remedy than keeping the tree in good condition by proper cultivation and fertilization.

5. An infestation on the tops of trees may be destroyed by spraying with a nicotine solution as before described. This spray may be applied at any time, but the greatest numbers of aphids are usually present during the autumn months. If the trees are young it is practicable to carry a pail of nicotine solution from tree to tree and apply it to the colonies with a paint brush.

TECHNICAL SECTION

BIOLOGIC PHASES

The biology of apple aphids has received attention from many entomologists, principal among them being Baker (1), Baker and Turner (2-3-4), Patch (21-22-23), Mathewson (18), Lathrop (15-16-17), Peterson (24-25), and Davis (8). The reader, therefore, has available many excellent accounts of the life history and general biology of the several species attacking apple. For this reason it was not thought necessary to conduct detailed studies along the lines designated above. In outlining the problem, control work with the three species, *Rhopalosiphum prunifoliae*, *Anuraphis roseus*, and *Aphis pomi* was given the greater portion of the time available. Work of a biological nature was attempted with *Aphis pomi*, where the factors constituting environmental resistance were studied. The factors that might determine or forerun an outbreak of this species were also studied. Life history work with the other two species consisted of notes taken in the field, dealing largely with seasonal activities. These have been incorporated in the popular section.

1. Predicting outbreaks of *Aphis pomi*.—Little mention is made in the literature of possible means of predicting undue abundance of the green apple aphis. Certain factors, such as "abundance of eggs", "amount of migration", "absence of natural enemies", and "growth condition of the host", have all been considered as possible indicators. The first three factors, while each undoubtedly has an effect on the ultimate abundance, are all open to the same objection; namely, that they are not obvious, and require too much detailed attention to determine the actual situation regarding them. The fourth factor, "growth condition of the host", is very valuable in the later part of the growing season of apple. During this period, if the terminals have started to harden, even though aphids are abundant, the danger of a further outbreak amounts to almost nothing. However, early in the season when all trees are making growth, it is very difficult to define the degree of growth that would prohibit or would permit an outbreak because of the difficulty of judging the other factors operative at this time.

With the above situation in mind an effort was made to locate some other factor, obvious in character and easily evaluated, which

was correlated with green aphis outbreaks and might be used as an indicator. Since 1921 there have occurred in northern Ohio four severe outbreaks of *Aphis pomi*, 1922, 1925, 1927, and 1929. In the same years there also occurred outbreaks of the black cherry aphis, *Myzus cerasi* Fab. Furthermore, these outbreaks usually preceded those of *Aphis pomi* by from 3 to 4 weeks. If this condition held good over a long period of time, such outbreaks of the black cherry

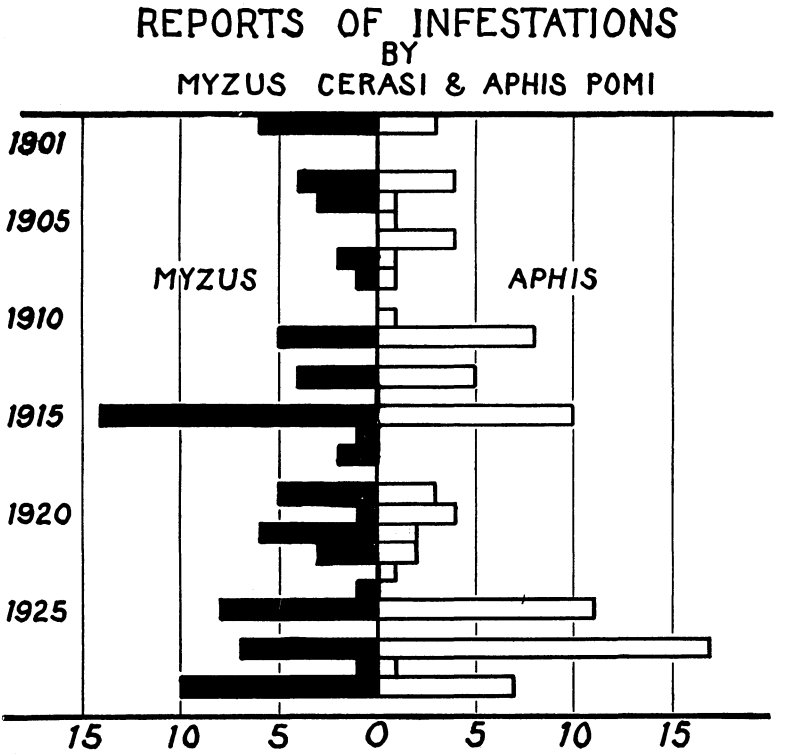

Fig. 11.—Infestations by *Aphis pomi* and *Myzus cerasi* as shown by reports received by the Department of Entomology 1900 to 1930

aphis would lend themselves to predicting undue abundance of the green apple aphis. In search for further data to substantiate this idea the correspondence records of the Department of Entomology at Wooster, starting in 1900, were consulted. The series of records dealing with letters accompanied by specimens was used and from it Figure 11 was derived.

The data depicted graphically in Figure 11 show that in each year when many specimens of one of these species were received,

specimens of the other also appeared in considerable numbers, thus establishing a direct correlation between the appearances of the two species. When these data are subjected to statistical analysis we find the measure of association or correlation coefficient to be .7716 with odds of over 3,333,333 to 1 that the data are significant. Figure 12 shows the scatter-graph (correlation table) from which the correlation coefficient and the odds were calculated.

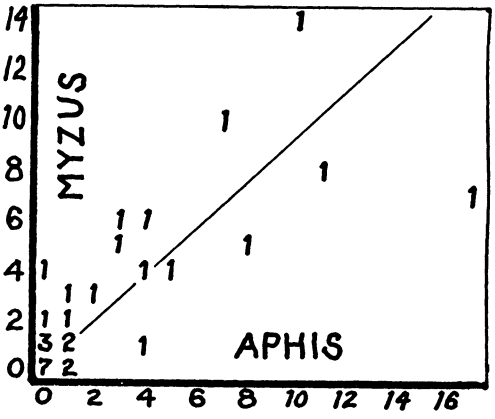

Fig. 12.—Correlation table showing the relation between infestations of *Aphis pomi* and *Myzus cerasi* as they occurred over a thirty-year period.

The next point to be confirmed is that the outbreaks of *Myzus cerasi* precede those of *pomi* by an interval of time sufficient to permit of practical prediction. For this purpose the dates of all specimens of both species received from 1919 to 1929 inclusive were plotted according to their date of arrival. The result is given in Figure 13, which shows that the date of receipt of the maximum reports of *cerasi* was June 13 while that of *pomi* was July 12, thus giving a time interval between the peak of abundance of the two species of at least four weeks. When these data are transferred to a correlation table we find a negative correlation coefficient of .5916 with odds of 249-1 that the separation of dates is significant. Thus it is evident that outbreaks of *Myzus cerasi* are definite forerunners of outbreaks of *Aphis pomi.*

2. **Environmental resistance as affecting** *Aphis pomi.*—Because of the high biotic potential of aphids, thousands of attempts to control them fail, even tho a high per cent of mortality may be obtained at the time of treatment. The impressiveness of the many failures of artificial control has created a great deal of interest in the factors of natural control or environmental resistance. In these insects the different natural processes appear, disappear, and reappear in rapid succession, thus furnishing the necessary changes within a reasonable period of time. This is well illustrated by the fact that *Aphis pomi* may on a certain date be so rare that only a few individuals can be found even after a long search.

However, in a month from that time the insect may have become so abundant as to cause serious damage to the fruit and foliage of apple. In this section dealing with environmental resistance as affecting *pomi* the data contained in the literature as well as the research experience of the writer are included.

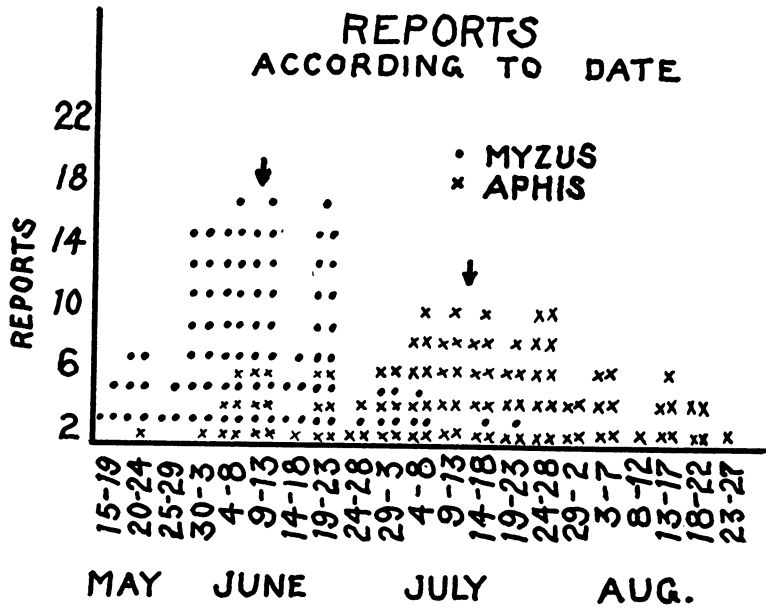

Fig. 13.—Chart showing the dates of reports received by the Department of Entomology concerning infestations by *Aphis pomi* and *Myzus cerasi*. Arrows mark the mean date of report receipt for each species.

The factors that make up the resistance to which *Aphis pomi* is subjected may be summarily grouped as follows:

1. Weather conditions.
   Temperature, humidity, rain, wind, light, etc.
2. Biotic factors.
   Predators, parasites, and diseases.
3. Nutrition.
   The growth condition of the host.
   Competition for food.

Whenever the possibilities of the insects' reaching outbreak proportions arise, the factor of initial population must also be considered. This factor forms the basis for all control work, mechanical and biological. Control consists in reducing the population to

such an extent that the surviving individuals are not numerous enough to reproduce in sufficient numbers to cause commercial damage over a given period of time, usually that required for a host crop to mature. However, the initial population of *Aphis pomi* as determined by the factors enumerated above cannot be considered

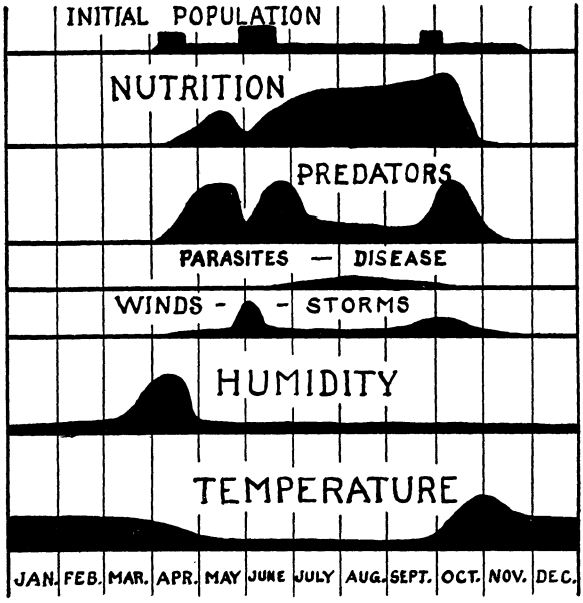

Fig. 14.—Environmental resistance affecting *Aphis pomi*. The dark areas show the amount of influence and the time when each factor usually operates.

as a part of environmental resistance. Due to the difficulty of obtaining exact measurements of any factor, the effects of large fluctuations of the population of *Aphis pomi* only can be considered here and an attempt be made to judge the importance of the factors on this basis.

FACTORS AFFECTING THE EGG

In Ohio there is no evidence that the insect overwinters other than in the egg stage. Whatever the host plant may be on which the eggs are deposited, Patch (23), the resistance that they encounter to successful overwintering and hatching is practically the same. In the brief discussions of the various factors that affect the eggs it should be understood that only normal, fertilized eggs are being considered.

1. Temperature.—It has been shown by Baker and Turner (2), and later by Peterson (24), that a long period of continued cold weather is necessary to the wellbeing of the eggs of this species. The eggs of other species common to apple may be brought indoors during the winter and will hatch at almost the normal rate. Eggs of *Aphis pomi*, however, do not react in this way; practically all of them die. This is explained by the work of Baker and Turner (2), who showed that the egg upon deposition developed to a certain stage in which it "rested" for the winter. In early spring the embryo revolves and development then proceeds largely according to temperatures. However, a period of high temperatures occurring before the revolution of the embryo is fatal to the egg. This fact is considered by these workers as largely explaining the high mortality among the eggs of *Aphis pomi*, a condition that has been noted by all who have worked with this species.

2. **Humidity.**—This factor is considered by Matheson (18) and by Peterson (24) as being very important in relation to the per cent of eggs that hatch. Both agree that its chief effect is felt during the period after the outer covering of the egg has split. Matheson's ideas are based largely on general observations and Peterson's on both laboratory and field experiments. The laboratory work of Peterson (24) indicated that the higher the humidity, the better the eggs hatched. Peterson believes that this explains the high mortality among the eggs of *Aphis pomi*, especially in the western United States. Baker and Turner (2) conducted a limited experiment relative to the effects of humidity on the hatching of eggs and concluded that it was of little importance.

TABLE 1.—Hatching of Aphid Eggs

Collection date	Per cent of hatch	
	Dry lab.	Damp lab.
March 8	½%	4%
March 13	3%	24%

In dealing with eggs of *pomi* that were being used primarily for control work it has been noted consistently that if they were brought directly into a heated laboratory they failed to hatch even tho the humidity in the room was near normal—50-70 per cent. This applies to eggs collected in late February and early March. Later in the season, as the normal hatching period approached, the eggs brought into the laboratory hatched in increasing percentages. Table 1 shows this tendency.

The above test also shows the increased per cent of hatching secured when twigs carrying eggs of *pomi* were held under moist conditions. An average of above 400 eggs was used in each of the above four lots. On March 8 an additional lot of 1140 eggs on twigs was collected and counted. The twigs were placed in water in an Erlenmeyer flask and at once placed in a 5° C. constant temperature cabinet. In this they remained two weeks, then were shifted to a 10° C. cabinet for a week, and then to one maintaining 15° C. after which they were placed in the dry laboratory. One hundred and sixteen aphids hatched, giving an average of over 10 per cent in comparison with the lot of March 8 kept continuously in the dry laboratory that hatched only one-half of one per cent. It would seem that the gradual increase in temperature secured by shifting the eggs from cabinet to cabinet was decidedly favorable to hatching.

From these experiments and from the work recorded in the literature it is evident that both temperature and humidity play important parts in relation to the hatching of eggs and that these factors vary widely in their importance from year to year. Neither or both may operate adversely or otherwise during a given season. For this reason it would be little more than a guess to state that one was of greater importance than the other.

Other weather factors, such as rains, winds, light, etc., do not directly affect the egg to any great extent but influence it indirectly through their effects on temperature and humidity. Baker and Turner (2) state that in autumn while the egg is undergoing its brief period of development prior to entering the resting stage sudden drops in temperature are fatal to it.

References to predators, parasites, or diseases attacking the eggs are not found in the literature nor have these influences been noted in Ohio in these studies.

FACTORS AFFECTING THE STEM MOTHERS AND THEIR IMMEDIATE PROGENY

1. **Weather conditions.**—It is a common experience to find high percentages of the stem mothers of *R. prunifoliae* dead on the buds due to severe frosts and late spring freezes. At first thought one might expect to find the same condition applying to *Aphis pomi* but such is not the case. Data taken at Wooster show that the peak of the hatching of *prunifoliae* practically always occurs two weeks before that of *pomi* and it is during these two weeks that such severe changes in temperature usually occur. Newly hatched

pomi, therefore, escape the more severe frosts that are so detrimental to the apple-grain aphis. At times, freezes undoubtedly kill some of the stem mothers of *pomi* but in Ohio the factor of low temperature after the eggs hatch has little effect on the abundance of the species. Development is retarded, of course, and this seems to be about the only effect of low temperature. In fact, there is some evidence to show that *pomi* is more resistant to cold than *prunifoliae*.

Humidities as they occur in the open during the period of development and reproduction of the stem mothers are not sufficiently variable to cause any significant mortality among them. This has been shown by laboratory experiments of Headlee (12) and others and has also been confirmed by the field observations of many workers. Other weather factors also usually play unimportant roles as far as the abundance of stem mothers is concerned.

2. **Biological factors.**—Parasites and disease are of little importance in influencing the abundance of stem mothers, but predators are at times of great importance, not only in regard to the numbers of stem mothers themselves, but also because these and their immediate progeny constitute the initial population that may later develop to outbreak proportions. As has been stated before, it is an axiom in control work that a population may be so low that it is biologically impossible for it to develop the numbers necessary for commercial damage. If predators are unusually abundant and are favored by warm weather it is possible for them to accomplish this by attacking the stem mothers and their progeny when their numbers are low. The season of 1928 in Ohio illustrated the above condition.

3. **Nutrition.**—The food of the stem mothers and its effect upon them and their progeny has not received a great deal of attention from aphid workers. Baker and Turner (2) state that, if food is not suitable, the stem mothers wander about over the twigs and seldom settle down and reproduce. This fact, however, is not emphasized by them as causing any striking reduction in numbers.

At the period when the stem mothers first emerge from the eggs and for some time thereafter, available food is in a much more uniform condition than occurs at any other time during the growing season. All workers in the East have noted that a high percentage of the first generation develops wings, usually about 75 per cent. The regularity with which this percentage of individuals develops wings each year is due largely to the uniform type of food that is then available. If more fluctuation in growth could be produced the percentage of winged forms would likewise vary.

Lathrop (16-17) has shown that in Oregon the eggs of *pomi* hatch over a much longer period than in the East; therefore, the young stem mothers find food in several different stages of growth. The percentage of aphids that develop wings under such conditions varies markedly. The effect of food in different conditions of growth on the reproductive capacities of the stem mothers is not known. However, there is considerable evidence to indicate that it is a factor of importance in affecting the initial population of migrants that forms the basis of possible outbreaks later in the season.

FACTORS AFFECTING MIGRANTS AND THE SUMMER GENERATIONS

1. Weather conditions.—Temperature cannot be seriously considered as the limiting factor in the abundance of *Aphis pomi* during the summer months. With other factors favorable, reproduction and development continue with sufficient momentum throughout the usual range of summer temperatures so that, unless other factors intervene, the species will increase in numbers. These facts may appear contradictory to the important work done by Lathrop (16) with *pomi* and by Headlee (12) and Davidson (7) with other aphids. However, as we are considering the insect in outbreak proportions, a period of at least six weeks during the summer months must be considered. Lathrop's data show that from May 31 to September 2 the greatest variation in the developmental period of growing aphids on similar food was 5 days. With other factors favorable, low temperature will not stop an outbreak, as has been shown by data collected at Wooster. On the other hand, if other conditions are unfavorable, high temperature alone will not promote undue abundance of the species. In Ohio, during the summer months, weekly mean temperatures average considerably higher than those in Oregon at the scene of Lathrop's work. In six years at Wooster, during June and July, the lowest weekly mean temperature was 55.5° F. and the highest 77° F. The average was 67.3° F., a figure appreciably higher than Lathrop's. Also, as is shown by Lathrop's curve, when the mean temperature is above 65° F., the increase in length of the developmental period becomes proportionally much less than in the lower ranges of temperature. In other words, at temperatures between 50 and 60 degrees the developmental period may vary 10 days in length; at temperatures from 60 to 70 degrees, it varies only about 3½ days. Therefore, in Ohio with the higher average temperatures, the

fluctuation would not mean nearly as much as regards a possible population as in Oregon. Also during July and August when temperatures are highest, food conditions are not nearly as favorable, thus further decreasing the value of the temperature factor. Data taken at Wooster, Ohio, show that for a six-year period, 1923-28 inclusive, the most severe outbreak of *pomi* ever experienced extended over a 9-week period in which the mean temperature was the lowest of any of the six years. An outbreak second in severity occurred during the period with the highest mean temperature. From all the foregoing data we can but conclude that the use of temperature as a gauge of abundance of *pomi* is unsatisfactory.

Likewise humidities within their normal range have little effect on the summer generations. Dashing rains and winds have been mentioned by many authors as being destructive, especially to winged forms. This is true and a certain number of aphids are undoubtedly destroyed by such agencies. However, observations before and after rains in orchards make it appear quite doubtful if the numbers are significantly decreased. In control work a 99% mortality is necessary to be effective and it is doubtful if a decrease of over 10% of winged forms is ever brought about by rains and winds. Wingless forms are affected even less than are the alate individuals.

Except under conditions of severe infestation *pomi* is usually found in the inside of the tree feeding on water sprouts. This is a reaction to food and by no means should be misinterpreted as negative heliotropism.

2. Biological factors.—As was the case with the stem mothers and the first generation, parasites and disease are of little importance in controlling the numbers of *pomi* during the summer months in Ohio. A parasitized green apple aphis is very rare and diseased individuals are even less common. Patch (23), however, records a fungous disease as important in reducing the number of *pomi* in certain years.

Before discussing the role of predators, the factor of initial population should be presented briefly. Before any migration occurs, the stem mothers and their immediate progeny are grouped in isolated colonies. Without migration, the distribution of the species at this time is entirely inadequate to produce a possible outbreak later on. The successful migration and location of a large number of alate females is, therefore, necessary to establish a distributed initial population large enough to produce the mass of insects necessary to constitute an undue abundance. The time in

which an outbreak develops is usually limited to about 6 weeks, and a population of reduced numbers and poor distribution cannot increase to outbreak proportions in this time. It has been shown that abundant predators may largely affect the number of individuals available for migration. Likewise, numerous predators may attack the alate females and their immediate offspring soon after migration and greatly reduce their numbers. If, however, the migrants are undisturbed by predators for a short time, with other factors favorable, their numbers increase so rapidly that even numerous predators later on have little effect on the population. The writer has never seen an outbreak of *pomi* that, in his estimation, was brought to an end by predators.

3. Nutrition. a. The condition of food or growth condition of the host.—(1) Data from Lathrop (16) show that the developmental period of *pomi* may be doubled in length by poor food. Observations and data of the same character have also been taken by Baker and Turner (2), and others. In Ohio, soon after midsummer it is frequently noted that apterous *pomi* on terminals that have just hardened tend to cease growth and certainly do not reproduce. These aphids continue to live and seemingly are just able to maintain themselves on the hardened foliage. Such individuals have lived under observation for over two months, and periods of over six weeks of life are very common. This condition has been noted both in the field (where it is frequently broken up by predators) and on trees in screened inclosures. Considering the fact that such conditions occur during the very warm weather of late July and August, it shows a remarkable effect closely approaching aestivation due to the unfavorable condition of the food.

(2) Poor food, such as terminals in a weak condition of growth or those that have hardened, is avoided in large part by migrants. On unfertilized, uncultivated trees there is a much less rapid accumulation of migrants than on cultivated and fertilized trees of the same variety. This has been shown by data taken from such plots at Wooster.

Experiments carried on at Wooster in 1929 further illustrate this fact. For this work a large number of apple terminals, half of which had hardened and half of which were still actively growing, were cut from trees of the same variety and placed at once in water. On each twig there was then placed an equal number of *pomi* migrants that had been taken from old colonies. The results taken at the end of 48 hours are shown in Table 2.

These results, with significant odds of 27.5-1, lead us to believe that the growing terminals were at least four times as attractive to the migrants as were the non-growing.

TABLE 2.—Percentage of Migrants Remaining on Growing and Non-growing Terminals

	Growing terminals	Non-growing terminals
Experiment 1	33%	12%
Experiment 2	50%	4%
Experiment 3	22%	12%
Experiment 4	8%	0%
Average	28.2%	7.5%

In the field, even more conclusive data have been collected. For example, on July 22, 1929, when about four-fifths of all terminals had hardened, in a count including 562 terminals, not a single hardened terminal was tenanted by migrants while the actively growing terminals were over 10 per cent infested. Such data have been duplicated many times in the past few years.

(3) Mature individuals located on poor food give birth to young at a slower rate and also in fewer numbers. This fact is common not only to *pomi* but also to almost all species of aphids. The same experiments that furnished the data given in Table 2 also supply information on this point. Reproduction records of all the migrants locating on growing and non-growing terminals were taken and these are summarized in Table 3.

TABLE 3.—Reproduction per Individual Migrant on Growing and Non-growing Terminals

	Growing terminals	Non-growing terminals
Experiment 1	6.0	.7
Experiment 2	3.3	1.0
Experiment 3	5.4	3.0
Experiment 4	11.0	.0
Average	6.3	1.2

These data, with favorable odds of 72-1, show that the individual located on a growing terminal produces almost six times as many young in a given period of time as does one located on a terminal that has ceased growth. Similarly, field observations fully confirm the above figures. Such a difference is indeed significant when the factors governing outbreaks are to be considered.

Once the aphids are located on a terminal the amount of reproduction that follows can be correlated directly with the amount of growth that the terminal makes. This is shown clearly by the following experiment. On June 3, 1929, five migrants were placed on a growing terminal of each of six young potted apple trees that were held under wire screen. The following day the migrants were removed, and ten newly born aphids were left on each terminal. At the end of 31 days the terminal growth of each tree was measured and the number of aphids on it counted. In all instances some aphids had migrated from the original to other terminals on the same tree and these, together with the growth of the terminal, are included in the figures in Table 4.

TABLE 4.—Amount of Terminal Growth and Number of Aphids Produced From a Given Original Number

Tree	Centimeters growth	No. of aphids	Tree	Centimeters growth	No. of aphids
1	5.5	322	4	9.6	621
2	6.0	368	5	20.8	1150
3	7.2	460	6	25.1	1181

When the factors of growth and reproduction are correlated the remarkably high measure of association or correlation coefficient of .9703 is the result from which significant odds of 2221-1 may be calculated.

In the field, vigorously growing terminals are frequently noted infested by large numbers of *pomi*. Close by are less vigorous terminals upon which the population is much less. In view of the foregoing data there is little doubt that these populations originally started with about the same number of lice and that the great difference in final population is due to difference in food.

(4) The percentage of winged forms (migrants) produced on non-succulent foliage is much higher than on favorable food. This has been shown for *pomi* by Cutright (5), and has been corroborated by Walley (26) and Ewing (9) with other species.

(5) Young born on poor food frequently leave it and wander about, never settling permanently, Baker and Turner (2).

Complete data supporting the above points will be found in the references cited. When the great effect that can result from all the above factors working together is considered, there is little doubt left that nutrition is the chief factor relative to outbreaks of *pomi* and their degree of severity. This is true provided that the initial population is of sufficient numbers.

b. Competition for food.—Many investigators have noted that when the host becomes crowded with aphids, migration usually follows soon thereafter. This has usually been interpreted as meaning that food was not sufficient for all and that the lessened amount or quality caused the production of winged forms. That this view is essentially correct is shown by the work of Gregory (11), Wadley (26), Ewing (9), and others. Will this fact greatly affect the length or severity of an outbreak of *Aphis pomi* in the field? While there is undoubtedly some effect, a study of the growth and decline of the colony in the open seems to show that as long as the terminal is growing it produces food for its inhabitants, even though crowded. Colonies have been observed that lasted for over six weeks, and for at least a month these could be said to be crowded. However, as the terminals were still growing, no significant number of winged forms were produced until growth stopped and hardening began. Crowding, therefore, cannot be considered as the factor which dominates the production of winged forms.

FACTORS AFFECTING FALL MIGRANTS AND SEXES

Since Patch (23) has shown that *pomi* spends the summer on a large number of hosts in addition to the apple, it might be inferred that in the autumn return migration to the primary host would take place. It is entirely possible and probable that this does occur but whether or not the amount is of economic significance has not been definitely determined. The writer has found in autumn a few isolated groups of sexuals that might have had their origin in this way, but they were indeed rare as compared to the main groups of large numbers of sexuals that came from hold-over colonies from summer infestation. The very nature of egg deposition by *pomi* as it is known in Ohio is of considerable importance as an argument against the economic significance of return migration. In this case *pomi* escapes the hazards of migration as they affect species such as *roseus* and *prunifoliae*.

1. Weather factors.—Temperature is important in the life economy of the species during autumn. Field data taken by the author indicate that reproduction is checked at 40° F. If temperatures of this mean persist over periods of any great length, reproduction definitely ceases. The sexes and the alate migrants, however, can stand quite low temperatures if these are not of too long duration. If periods of relatively high temperatures again occur, both reproduction and oviposition will be resumed.

The onset of periods of minimum temperatures for oviposition varies greatly from year to year. In 1924 eggs were deposited in numbers till after November 20 when prevailing low temperatures started. In 1925 there was practically no oviposition after October 21 as mean temperatures from that time on were below 40° F. If other factors delay the production of the sexes and low temperature starts early, the amount of oviposition will be very light as it was in 1925. Other weather factors seem to exert about the same influence that is noted at other seasons of the year. Humidity seems to have some effect on newly deposited eggs but unless it is outside the usual autumnal range it is of little significance.

2. **Biological control.**—Parasites and disease are of practically no economic significance during the autumn months. However, populations of predators that have been built up during the summer months may become quite important during September and early October. If at this time unfavorable food has reduced the population of *pomi*, the remainder may be almost overcome by the predators. Such a condition was noted in an orchard at Wooster in 1926 where a noticeable reduction of the form that would soon have produced the sexes was noted. After early October the importance of predators depends quite largely on temperatures.

3. **Nutrition.**—In late August and during September most terminals on apple have ceased growth and have hardened, a food condition very unfavorable to *pomi*. Only a few terminals on young trees and water sprouts on old trunks are still growing. On wood of this nature, the colonies that will soon produce the sexuals are located. Thus, the limited food at this season definitely prevents the amassing of large populations that would eventually produce eggs in vast quantities. While in autumn only a very few terminals offer favorable food, in spring as the buds open almost all terminals are in suitable condition to support aphid colonies. If the autumn food condition were equally favorable, the seriousness of *pomi* as an economic pest would be greatly increased provided other resistance factors remained the same.

Terminals infested in September may either harden in early October or continue growing till late in the month. It has been observed at Wooster that colonies infesting the early hardening shoots produce sexuals sometimes as much as three weeks in advance of colonies located on the late growing shoots. This interesting food effect on the production of the sexes is also of importance as ultimately affecting the number of eggs deposited, and, when considered in connection with possible temperature ranges and predator abundance, it becomes quite significant.

4. Competition for food or crowding.—This factor is frequently mentioned in the literature in relation to the production of sexes. From observations in the field at Wooster it seems that this point has been overemphasized. Large and small colonies have produced sexes at the same time if the growth conditions of the terminals on which they were located were the same.

DISCUSSION

It might seem to some that, in this paper, the direct influence of weather factors on *pomi* has not been sufficiently stressed. The important place that nutrition holds in the life of the species is a proven fact but it is not a factor that stands alone. The growth condition of the host is directly influenced by the various weather factors, and the writer conceives of their greatest influence as being expressed through the host or indirectly rather than directly upon the insect. *Pomi* is also influenced indirectly by the fertility of the soil occupied by the host, by cultivation, and by pruning. The many factors brought to bear on the species because of its dependence on the host are of greatest significance. In selecting for experimental work the important factors from among the many that compose the environmental resistance, those should be chosen that are pliable and can be changed, so that in time they may have a direct economic bearing. In this respect none are more suitable for experimental use than the host and its various phases of growth.

CONTROL PHASES

The popular section of this paper contains certain recommended control measures that may be used against the different species of aphids. It is the purpose of the technical section to give in more or less detail some of the important parts of the experimental work that have led to the recommendation of these measures.

DORMANT AND DELAYED DORMANT SPRAYING AGAINST APPLE APHIDS

Theoretically the terms "dormant" and "delayed dormant" mean entirely different things. "Dormant" is meant to include the period in early spring which precedes the appearance of any foliage; fruit buds may be swollen and still be considered dormant. The "delayed dormant" is the period from the appearance of the smallest leaves until they have reached a length of three-fourths inch. Sprays suitable to either or to both of these periods have been

recommended, but the orchardist working under the stress of varying seasonal conditions has used them rather indiscriminately. At times, certain sprays applied in the delayed dormant have caused serious losses tho usually no ill effects of long standing occur. Peterson (24) working with the eggs of aphids has shown that the nearer these eggs approach hatching, the greater the mortality caused by sprays. Other workers have shown that this also holds good with reference to the eggs of other insects on apple, whose normal hatching period roughly coincides with that of the aphids. This has generally caused the later application of sprays. Because of the fact that spraying in the dormant and delayed dormant periods is so often an affair of a single operation, spraying against apple aphids in the two periods will be considered under one head However, notes that will be given in connection with each experiment usually show quite definitely in what period the experiment will fall.

The different species of apple aphids as discussed in the popular section are generally distributed thruout Ohio but the more severe outbreaks of rosy and green apple aphis seem to occur with greater frequency in the northern part of the State. For this reason most of the field work was conducted in this section of the State, though the experiences and observations of growers thruout the State have been used in formulating conclusions.

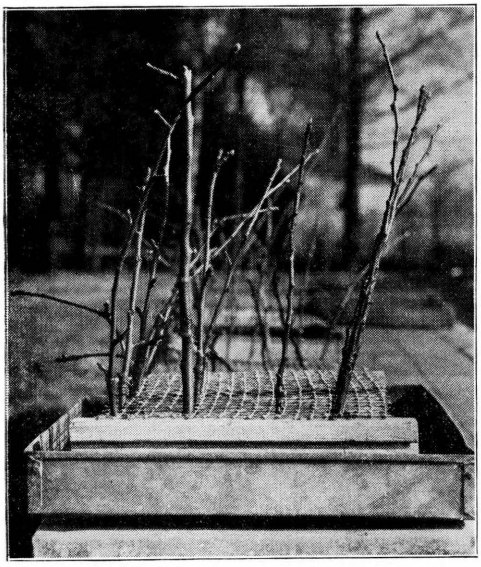

Fig. 15.—Apple twigs carrying aphid eggs arranged for laboratory spraying

TESTS OF SPRAY MATERIALS AGAINST APHID EGGS

Before presenting the data dealing with field tests, some experimental work of a laboratory nature with different spray materials against aphid eggs will be given because any spray applied to trees during dormant or delayed dormant periods should act not only against the young aphids but also against the eggs which hatch continuously during this entire time. Due to the

fact that large numbers of aphid eggs are the exception rather than the rule, work of any great amount was possible during two seasons only. The eggs of *Rhopalosiphum prunifoliae*, with a small per cent of *Anuraphis roseus* mixed in, were used exclusively for these tests. Twigs carrying the overwintering eggs were cut from the tree and the cut ends placed in water. They were kept out doors under natural weather conditions and were brought into a warm room for only a few minutes while the eggs were counted and recorded. They were then arranged in suitable groups in shallow pans (See Fig. 15) and were sprayed. Individual twigs were banded with tanglefoot to prevent the escape of hatching aphids. As the hatching season approached, the unsprayed checks were inspected daily and as soon as young aphids were noted the entire series was carefully examined and the hatched aphids on each set counted. This inspection was repeated at suitable intervals until the hatching season was over. In order to be accurate all examinations were made under a binocular microscope. In the spring of 1924 aphid eggs were relatively scarce but enough were collected for the following experiment. The materials used and the results are explained by Table 5.

TABLE 5.—Different Spray Treatments Against Aphid Eggs

Spray material	Number of eggs treated	Number of eggs hatching	Per cent of eggs hatching
Check (no spray)	723	287	39%
Engine oil emulsion 2%	1951	215	11%
Sunoco spray oil 1-20	605	42	7%
Liquid lime-sulfur 1-7	343	15	4%
Check (no spray)	936	328	35%

At the time that this experiment was conducted there was a great deal of interest in the relative merits of the oil sprays in comparison with lime-sulfur as an ovicide. The foregoing results indicate that lime-sulfur alone is quite effective in the destruction of aphid eggs. This fact has also been noted in many instances by workers at other Agricultural Experiment Stations. The eggs used in this experiment were all approaching the hatching period and many of them showed the first rupture of the outer shell.

The autumn of 1924 was quite favorable for aphid oviposition, as there was a heavy migration with mild temperatures until late November. Apple trees also held their foliage later than normal, which is, in many seasons, a factor very favorable for oviposition. As a result, eggs were very numerous in the spring of 1925 and large collections were made so that it was possible to test several

spray materials adequately. The experiments were conducted along the same line as those of 1924. Table 6 summarizes the spray materials tested and the results that were obtained.

TABLE 6.—Spray Tests Against Aphid Eggs

Spray material	Eggs treated	Eggs hatching	Eggs hatching
	No.	*No.*	*Per cent*
Check (twigs from south side of tree) no spray	554	300	54+
Check (twigs from north side of tree) no spray	692	387	56—
Sunoco spray oil 1-20	849	96	11
Rex oil emulsion (1925) 3-100	787	22	3
Rex oil emulsion (1925) 4½-100	754	27	3+
Standard oil spray (test sample A) 4-100	731	45	6
Standard oil spray (test sample B) 4-100	728	64	9—
Conkey's Fruit Spray (creosote base) 1-50	724	199	29
Liquid lime-sulfur, 1-7	633	29	4+
Dry lime-sulfur, 15 lb.-50	709	35	5
Dry lime-sulfur, 15 lb.-50 Nicotine sulphate, 1-1000	810	7	1—
Dry lime-sulfur, 15 lb.-50 Nicotine sulphate, 1-1600 "Emulso" (soap-free oil) 1-100	706	0	0
Dry lime-sulfur, 15 lb.-50 Nicotine sulphate, 1-1600 Soap-free oil, 1-200	810	1	2
Dry lime-sulfur, 15 lb.-50 "Emulso" (soap-free emulsion) 1-100	822	24	3

From Table 6 we may conclude that oil sprays and the dormant strengths of lime-sulfur are about equally effective against aphid eggs and, also, that the addition of nicotine sulphate to lime-sulfur greatly increases its efficiency, a fact that confirms results obtained in many other states. The fact that Conkey's fruit spray (creosote base) killed only a small per cent of the eggs is additional proof of the accuracy of similar data taken in New Jersey, New York, Virginia, and elsewhere. The addition of small amounts of an oil that will mix with lime-sulfur to the lime-sulfur-nicotine spray in the two cases where it was used gave excellent results. In field experience this spray has not been as successful as expected due largely to the mechanical difficulties of application. The almost equal hatch of the two check lots, one taken from the south side and the other from the north side of trees, shows that there is little reason for the belief that eggs from these two situations hatch in unequal percentages. The eggs used in this experiment were collected and sprayed from March 22 to March 27 and were not as far developed as those used in 1924.

The season of 1926 was marked by an almost entire absence of aphid eggs so that no work could be attempted. In 1927 a very few eggs were present, and a few tests were conducted which dealt mainly with the addition of Derrisol and soap-free oils to lime-sulfur, also with the addition of Derrisol to oil. These tests can not be considered as final in that they did not contain eggs in

sufficient numbers to make the results definite. The results, however, seemed to show that little was gained by adding Derrisol to either lime-sulfur or oil sprays. Where a soap-free oil was mixed with lime-sulfur at dormant strengths, only 3% of the eggs treated hatched, which is the same as results secured in 1925. Work with aphid eggs was also hampered in 1928 by scarcity of numbers and only two materials were tested, these being a "Cresol" extract (Grasselli) used at ¼ of 1% and free nicotine, 1-1000, added to a 2% oil emulsion. In this series the check hatched 38%, the "Cresol" treated eggs 14%, and the free-nicotine-oil 16%. It was evident that the two materials used did not hold a great deal of promise in the control of aphid eggs. The scarcity of aphid eggs in four of five years in which work with them was attempted has greatly reduced the data that might have been secured. However, by adding our results to those that have been obtained elsewhere some definite conclusions are secured. It must be remembered that these results are based on spraying done in the late dormant or delayed dormant period and at this season the eggs are more easily killed than at other times.

1st. Lime-sulfur to which is added nicotine sulphate is, at present, the best known practical ovicide.

2nd. Lime-sulfur alone kills a large percentage of the eggs.

3rd. Various miscible oils and oil emulsions are somewhat more efficient as ovicides than lime-sulfur alone.

4th. The addition of free nicotine or nicotine sulphate to oil sprays has not given an increased efficiency sufficient to justify the extra cost.

LABORATORY EXPERIMENTS WITH NEWLY HATCHED APHIDS

The newly hatched stem mothers of *Rhopalosiphum prunifoliae* clustered on swollen buds were frequently used in insecticide tests of a laboratory nature. Twigs with buds heavily infested were cut from the tree, placed in water, and brought into the laboratory where they were sprayed or the twigs were cut immediately after the trees were sprayed. These methods have the advantage of securing exact data regarding the effect of sprays on the young aphids. Some laboratory work has been conducted each year since 1923 and it is manifestly impossible to give in detail all the experiments that were conducted. One table is therefore given as an example of the method and type of work. This is followed by a summarized discussion of results obtained.

TABLE 7.—Spraying Against *Rhopalosiphum prunifoliae* (Fitch)

Spray materials	Aphids treated	Aphids killed	Aphids killed
	No.	*No.*	*Per cent*
Nicotine sulphate 1-1600	847	49	18
Nicotine sulphate 1-1600 + Miscible oil 1-150	279	276	99
Nicotine sulphate 1-1600 + Miscible oil 1-200	255	251	98.3
Nicotine sulphate 1-1600 + Home-made oil emuls. 1-200	291	290	99.6
Nicotine sulphate 1-1600 + Home-made oil emuls. 1-400	438	436	99.5
Check	250	3	2.5

The above experiment deals with the use of various oil sprays as spreaders and liberators of nicotine. After numerous trials such as the above, it was concluded that as far as laboratory experiments were concerned, oils, either miscible or emulsions, were the best available materials for this purpose. The trials of these combinations in the field are discussed under the head of field experiments.

Derrisol, alone and in combinations with lime-sulfur and oils, was also tested. When used at strengths of 1-800, if all aphids were thoroughly wetted, satisfactory kills were obtained. Nicotine sulphate, however, has a significant advantage in that the same results may be obtained with lower strengths and at lower costs. These results are supported by field tests. Other derris products and extracts have been tried from time to time but Derrisol is by far the best preparation of this sort that has appeared to date.

"Insecto spray" (now sold as "Red Arrow"), a pyrethrum extract, gave excellent results when used at strengths recommended by the manufacturers. The cost of this material for extensive use in the orchard is at present somewhat high for practical purposes.

As a type of the experiments that were conducted by bringing in twigs after spraying in the field we give the following:

TABLE 8.—Spraying Against Aphids

Delayed dormant application 1925

Materials used	No. of aphids	Per cent dead
Dry lime-sulfur 15 lb.-50 gal.	130	2
Liquid lime-sulfur 1-7	186	11
Dry lime-sulfur 15-50 + Soap-free emulsion 1-50	96	93
Standard Oil spray 1-50	205	94
Rex oil emulsion 4½-100	94	90
Check—no spray	102	0

Experiments such as the above confirm numerous observations to the effect that lime-sulfurs do not destroy any appreciable number of hatched aphids. A very good idea is also obtained as to the mortality obtained by field spraying when oils, that ordinarily give nearly 100% in the laboratory, are used. Further experiments have shown that oils used for dormant and delayed dormant spraying in the control of apple aphids should contain at least 2% of oil for the best results.

Oils used for summer or foliage spraying are not to be considered in this statement, as a satisfactory control of aphids may usually be secured with dilute nicotine-oil sprays of lower oil content. Numerous experiments were conducted with lime-sulfur in combination with various soap-free oils as it was hoped that increased killing might result. The results showed that in such cases the mortality obtained depended quite largely on the per cent of oil in the mixture and not on the concentration of the lime-sulfur.

FIELD EXPERIMENTS AGAINST APPLE APHIDS. DORMANT AND DELAYED DORMANT SPRAYING

Field experiments dealing with the control of apple aphids in the periods named above were conducted in 1924, 1925, 1926, 1927, 1928, and 1929. Most of the work was done at points some distance from Wooster, though spraying was also conducted here for several seasons. In taking results a system somewhat different from that usually employed was used. This consisted of counts taken in the different plots at dates approximately a month after the spray was applied. It is believed that this method gave a much better "check" on what actually happened than if the counts were made a day or so after spraying. It at least showed whether enough aphids had survived the spray to produce an infestation in a period of a month. In the field work, trees varying in number from 12 to 36 per plot were used, these being uniform as to variety, age, location, and cultural and fertilization practices. In order to secure good coverage no trees older than 16 years of age were used at any time. At all times notes were taken on injury to foliage and buds that occurred following the application of sprays, particularly with combinations of oils and fungicides. These notes have been summarized and published in the Bimonthly Bulletin, Ohio Agricultural Experiment Station, Vol. 14, pp. 42-45, March-April, 1929.

The only unfortunate thing that has constantly occurred during the six years of field experimentation has been uniformly low

infestations. In some years individuals of both the rosy apple aphis, *Anuraphis roseus*, and the apple-grain aphis, *Rhopalosiphum prunifoliae*, have been so scarce that no results worthy of note could be secured. In only two seasons, 1925 and 1929, were rosy aphids so abundant that counts could be obtained; otherwise all counts refer to *Rhopalosiphum prunifoliae*.

1. Experiments at Catawba Island, Ohio.

This work was conducted in 1925, 1926, and 1927. The writer is greatly indebted to Mr. George Rofkar, owner of the orchard in which the experiments were conducted, for his interest, time, and other valuable assistance.

TABLE 9.—Late Dormant Application, Catawba Island, O. 1925

Infestation of terminals by *Rhopalosiphum prunifoliae* 35 days after spraying

Materials	Terminals inspected	Per cent of terminals infested
Liquid lime-sulfur 1–8	532	20
Liquid lime-sulfur 1–8 Nicotine sulphate 1–800 (1 pt.-100 gal.) (Nicotine repeated in pink spray)	627	1—
Liquid lime-sulfur 1-8 Nicotine sulphate 1–400 (1 pt.-50 gal.) (Nicotine repeated in pink spray)	684	½—

The above materials were applied to the trees, using a power sprayer that maintained a pressure of about 200 pounds and with a spray gun that threw a fairly coarse type of spray. A good coverage was obtained. Trees were about 12 years of age and the varieties were Stayman, Delicious, McIntosh, and King David. The results show a significant reduction in infestation by the apple-grain aphis when nicotine sulphate was added to lime-sulfur. As the owner had suffered considerable loss from rosy aphis in the preceding year, nicotine was also added in the pink spray as an extra precaution. The count of infested and non-infested terminals hardly shows the real margin of difference between plots, since, in the case of the lime-sulfur sprayed plots, many of the infested terminals had literally hundreds of aphids on them while on the other plots infested terminals had only a few aphids present.

Later in the season a special count was made for damage by the rosy aphis to foliage. The results are shown in Table 10.

All damaged leaf clusters or terminals on each tree are included in this count. As the number of trees inspected in the plots sprayed with nicotine was twice that in the lime-sulfur

TABLE 10.—Injury to Foliage by Rosy Apple Aphis, Catawba Island, O., 1925

Materials used	Number of trees inspected	Number of terminals damaged by rosy aphis
Liquid lime-sulfur 1-8	8	702
Liquid lime-sulfur 1-8 Nicotine sulphate 1-800	16	32
Liquid lime-sulfur 1-8 Nicotine sulphate 1-400	16	17

sprayed plot, the number of damaged terminals here is multiplied by two so that the number in the last column is equalized. The same system is also followed in the count of damaged fruits that was made near harvest time. The results of this final check on the effectiveness of the sprays is shown in Table 11.

TABLE 11.—Fruits Damaged by Rosy Apple Aphis, Catawba Island, O., 1925

Materials used	Trees inspected	Number of fruits injured
Liquid lime-sulfur 1-8	8	362
Liquid lime-sulfur 1-8 Nicotine sulphate 1-800	16	45*
Liquid lime-sulfur 1-8 Nicotine sulphate 1-800	16	1

*All on a low branch of a King David tree.

This table shows the almost perfect control that was obtained by adding nicotine sulphate to lime-sulfur, despite the fact that 45 injured apples were found in Plot 2. As all these injured fruits were grouped on one low-hanging branch of a King David tree we can safely consider that this injury was due to faulty spray application. King David is one of the very susceptible varieties to attack by both rosy and green apple aphis. In the instance of the above experiment the King David trees in the lime-sulfur plot did not bear, and it is quite certain that if they had the margin of difference between the plots would have been much greater. Next to King David, Stayman showed the most injury, with Delicious and McIntosh carrying only a light infestation.

In 1926 and 1927 work was continued at Catawba Island, using combinations of lime-sulfur and oils, oils and nicotine, and lime-sulfur and nicotine. Unfortunately for the experimental work, however, no infestation developed in the orchard in either of these two years so that no definite results were obtained.

2. Experiments at Canton, Ohio.

Through the courtesy of James Ink, owner-manager of the Aplink Orchards of Canton, Ohio, field experiments in aphid control were conducted over a period of four years in the orchards at that place. The varieties used thru all the experiment were inter-planted—Jonathan, Delicious, and Wagner. All counts were taken equally from Jonathan and Delicious. Spraying in all four years was done just as the first buds were opening. A power sprayer that carried a steady pressure of over 300 pounds was used and the spray was applied to the trees with a gun. In 1925 the work was laid out to test an oil spray, the same with nicotine sulphate added, soluble sulfur alone and with different strengths of nicotine sulphate. A study in the time of application was made by applying to one plot lime-sulfur 1-40, plus nicotine sulphate, during the pink spray. The results are shown in Table 12.

TABLE 12.—Results of Delayed Dormant Spraying Against Apple Aphis, Canton, O., 1925

Materials	Terminals inspected	Per cent of terminals infested
Rex oil emulsion 3–100 (2% oil)	442	43
Rex oil emulsion 3–100 Nicotine sulphate 1–1600 (1 pt.-200 gal.)	494	23
Soluble sulfur 25 lb.-100 Nicotine sulphate 1–800	433	17
Soluble sulfur 25 lb.-100 Nicotine sulphate 1-40	372	6
Soluble sulfur 25 lb.-100	494	60
Pink Spray		
Lime-sulfur 1–40 Nicotine sulphate 1-1000	371	23

The infestation that developed in these plots consisted almost entirely of *Rhopalosiphum prunifoliae*. Very little injury by *Anuraphis roseus* was noted thruout the year. The efficiency of nicotine as a control material is clearly indicated by the results in this table.

In 1926 a series of seven plots designed to test the effect of varying strengths of oil and lime-sulfur on the efficiency of one strength of nicotine was planned. As no infestation developed in early season no results were secured. In early August a short-lived infestation of *Aphis pomi* developed but this was equally spread over all the spray plots as was to be expected.

The plots of 1927 were laid out with the same general idea in mind and the materials used and results are shown in Table 13.

TABLE 13.—Spraying Against Apple Aphis, Canton, O., 1927

Materials	Terminals inspected	Per cent infested
Check—no spray	198	24
Liquid lime-sulfur 1-7 Nicotine sulphate 1-800	243	2
Liquid lime-sulfur 1-7 Nicotine sulphate 1-1600	215	10
Liquid lime-sulfur 1-40 Nicotine sulphate 1-800	235	3
Liquid lime-sulfur 1-400 Nicotine sulphate 1-1600	217	14
Liquid lime-sulfur 1-40 Derrisol 1-800	231	17
Check—no spray	201	44

From the above results it appears that increased strength of nicotine is of much greater importance in effecting a control of aphids than is a strong-strength lime-sulfur solution. Derrisol at standard strengths does not appear as efficient as even the weak strength nicotine.

In 1928 the series of plots included tests of nicotine sulphate against free nicotine, Derrisol, and oil alone, but no results were obtained due to the failure of infestation to develop on the checks.

The series of field experiments at Canton yielded results in two of four years in which tests were conducted. From the experimental standpoint this was somewhat disappointing. However, the orchards, due to their age and growth, were very favorable to green apple aphis infestations, and a great many valuable observations on the biology of this insect were made at this place.

3. Experiments at Chagrin Falls, Ohio.

Work was conducted in the orchards of Halfred Farms, Chagrin Falls, O., from 1925 to 1929, inclusive.[1] The varieties used were largely Jonathan, Wealthy, and McIntosh. All work was done with an excellent power sprayer and materials were uniformly applied in each year with either rods or guns. In 1925, work was outlined with a series of oil sprays which were applied during the delayed dormant period. The materials used and the results against *Rhopalosiphum prunifoliae* are shown in Table 14.

From this table we may note that not a great deal of difference between the various oils is evidenced. This is quite noticeable when we consider that the oils were applied in different strengths usually according to the directions of the manufacturer. As was to be expected the sprays containing the higher oil content usually gave best results.

[1]The writer wishes to acknowledge the constant interest, courtesy, and aid of Mr. Ford Quigley, orchard manager.

TABLE 14.—Delayed Dormant Spraying at Chagrin Falls, O., 1925

Material	Terminals inspected	Per cent infested
Soap-free oil emulsion ..... 2 - 50 Dry lime-sulfur 7½- 50	268	41
Check—no spray	222	61
Soap-free oil emulsion ..... 3 - 50	228	20
Rex oil emulsion ..... 4½-100 Bordeaux ..... 1½-2 -200	237	18
Rex oil emulsion ..... 3¾-100 Bordeaux ..... 1½-2 -200	263	19
Scalecide ..... 1 - 15	258	14
Sunoco spray oil ..... 1 - 20	298	24
Check—no spray	258	62

Continuing the work with oil sprays, the following series of materials were applied each year to the same plot in 1926, 1927, and 1928.

Each plot included from 30 to 50 trees and was used to determine the effect of sprays on the various apple aphids, European red mite, and apple leaf hoppers. Notes were also taken as

TABLE 15.—Plot Outline, Chagrin Falls, O., 1926, 1927, and 1928

Plot	Material	Strength
1	Medina oil	1 - 20
2	Soap-free oil	6 -100
	Dry lime-sulfur	8 lb.-100
3	Dry lime-sulfur	30 lb.-100
	Nicotine sulphate	1 -800
4	Liquid lime-sulfur	1 - 7
	Nicotine sulphate	1 -800
5	Soap-free emulsion	6 -100
6	Rex oil emulsion	4½ -100
7	Rex oil emulsion	4½ -100
	Bordeaux	4-8 -100
8	Scalecide	1 - 15
9	Check—no spray	.....
10	Sunoco oil spray	1 - 20
	Soluble sulfur compound	4 lb.- 50
11	Colloidal clay emulsion	4½ -100
12	Colloidal clay emulsion	4½ -100
	Dry lime-sulfur	4 lb.- 50
13	Sunoco oil spray	1 - 20
14	Dendrol	6 -100
15	Medina oil emulsion	1 - 15

to the effect of the different combinations on buds and foliage. These have been published as heretofore noted. The notes taken on European red mite on the different plots were of much interest and shed much light on how the different oils affect this acarid. Notes on leaf hoppers were also of interest. Due to the fact, however, that no aphid infestation developed to any extent on the checks the notes on this insect were not of great significance. It seems, from the few figures collected, that lime-sulfur combined with nicotine sulphate was the most efficient material, but a definite conclusion to this effect could not be based on these experiments alone.

In 1929 various oils and combinations with lime-sulfur were again tried, but again no infestation developed on the checks so that no results were secured.

4. Experiments at Chardon, Ohio.

Experiments were conducted at Chardon, O., in the orchards of the late Dr. C. A. Bingham, from 1925 to 1928 inclusive. Power sprayers with rods and mist nozzles for the application of the spray were used in all this work.[2]

TABLE 16.—Spraying Against Apple Aphids, Chardon, O., 1925

Materials	Terminals inspected	Per cent infested
Check—lime-sulfur 1-30	466	61
Liquid lime-sulfur 1- 30 Nicotine sulphate 1- 400	407	18
Liquid lime-sulfur 1- 30 Nicotine sulphate 1-1000	445	27
Check—lime-sulfur 1-30	369	61
Liquid lime-sulfur 1- 30 Nicotine sulphate 1-1000	237	32
Pink Spray		
Liquid lime-sulfur 1- 50 Nicotine sulphate 1-1000	404	52

These materials were applied to the trees during the delayed dormant period and counts made as in all the other experiments one month later. The varieties involved were Baldwin, Stayman, and Jonathan. About 20% of the counted terminals included in the table were infested by *Anuraphis roseus* and the others by *Rhopalosiphum prunifoliae*. The failure of a spray applied in the "pink" is again to be noted and the better control obtained by the higher strength nicotine is significant.

[2]The writer wishes to acknowledge the constant assistance of Howard G. Ingerson, Manager, during the course of the work.

During the other three years in which work was continued at Chardon attempts were made to obtain data concerning the effectiveness of Derrisol and Coccotine in comparison with nicotine sulphate. Infestations, however, were so light that little definite information could be secured. These materials certainly are not superior to nicotine and Coccotine seemed to fall far short of equaling it. The same failure to secure data was also encountered on plots intended to compare miscible oils and various oil emulsions with each other.

4. Experiments at Wooster, Ohio.

From 1924 to 1929 inclusive, some field work has been done each year at Wooster during the late dormant or delayed dormant period. In 1925 an error in spray application lost all results.

In 1924 an opportunity was offered to secure data as to what occurred in the case of careless spraying. An aphicidal spray of liquid lime-sulfur 1-8, plus nicotine sulphate 1-1000, was applied to a plot of trees. The work was done hastily and without care in covering all terminals. From counts on *Rhopalosiphum prunifoliae* made soon after spraying it was estimated that about 85% of the aphids were killed. A month after the spray was applied further counts were made in which this plot was compared with one that had received only lime-sulfur. The results are given in Table 17.

TABLE 17.—Results of Careless Spraying, Wooster, 1924

Material	Application	Terminals inspected	Per cent infested
Liquid lime-sulfur 1-8 Nicotine sulphate 1-1000	Poor	404	53
Liquid lime-sulfur 1-8	Poor	373	46

Through careless application, as illustrated above, it is considered that the entire value of the nicotine sulphate in the spray may be lost. Results such as shown in Table 17 can usually be explained by the fact that enough aphids are killed so that natural enemies such as ladybird beetles leave the plot to seek for a more abundant food supply. This gives the aphids that escaped the spray an opportunity to multiply unchecked and they soon become as abundant as those on the check plot. To offset a condition such as this, sprays must be so applied that a mortality of from 98 to 99 per cent may be secured.

In 1926, due to the courtesy of the Department of Horticulture, a series of plots was arranged in a young orchard 5 years of

age at Wooster. Thorough application of the materials was made with a power sprayer and spray guns. Buds were swollen but no foliage had appeared. Table 18 gives the materials used and the results secured.

TABLE 18.—Spraying at Wooster, O., 1926

Materials	Per cent of terminals infested by *A. pomi* May 14, 1926	Actual colonies of *Anuraphis roseus* present June 21, 1926
Liquid lime-sulfur 1-7	2	0
Liquid lime-sulfur 1-7 Nicotine sulphate 1-1600	0	0
Liquid lime-sulfur 1-7 "Emulso" oil emulsion 3-100	2	2
Check-no spray	18	21
Rex oil emulsion 3-100	2	11
Rex oil emulsion 3-100 Nicotine sulphate 1-1600	4	13
Rex oil emulsion 3-100 Coccotine 3 pts.-100	4	6
Soap-free emulsion 6-100	½	2
Linseed oil soap 25 lb.-100 gal.	8	5

There was no infestation by *Rhopalosiphum prunifoliae*, and *Aphis pomi* and *Anuraphis roseus* were far from plentiful. All sprays used effected a measure of control as is shown by a comparison with the check. Hundreds of terminals were inspected in each plot so it is believed that the percentages are fairly accurate. The counts on *Aphis pomi* were made, of course, before any migration of this species took place. The surprising thing is that the addition of nicotine sulphate and Coccotine to an oil emulsion failed to give any increased control of the species at this season. This, however, has been noted in other experiments.

In 1927 the work was repeated, using practically the same materials as in 1926. The check plot in 1927 carried an infestation of 27% of terminals infested with *R. prunifoliae*, almost no other aphids being present. Again nicotine added to an oil emulsion failed to increase the efficiency greatly. The difference between the other sprays was so slight that no conclusions as to their value could be drawn. The work was again repeated in 1928 and, in part, in 1929. During these two seasons there was no significant infestation of the apple grain aphis and only light infestations of *Anuraphis roseus.*

In 1928 on the check plots rosy aphis colonies averaged 6 per tree, while on all the spray plots the number was about .2 colonies per tree. No difference between materials could be noted.

In 1929 results as shown in Table 19 were secured.

In this year no difference could be noted between several different oils nor was any advantage gained when free nicotine (Black Leaf 50) was added to the spray. This same result had also been noted in the previous year's experience.

TABLE 19.—Oil Sprayed Trees Compared with Checks, Wooster, O., 1929

Materials	Rosy aphis colonies per tree		
	May 1	May 24	June 8
Commercial miscible oil 1-20	0.2	2	6
Check trees-no spray	6.0	48	115

6. Experiments at other points in Ohio.

In connection with other experiments, work designed to obtain data on aphid control was also carried on in different years at Delaware and West Richfield, Ohio. Aphids were always present on the checks but the infestation was so light that no differences could be determined on the various plots.

SUMMARY OF RESULTS OBTAINED BY SPRAYING IN THE DORMANT AND DELAYED DORMANT PERIODS

In perusing the section of this bulletin dealing with control the reader has noted that only a small amount of the data deals with *Anuraphis roseus*. During six years in which work has been attempted with this species and in which spray work was conducted in at least five different orchards each year, it was only possible to collect data on this species in two instances, despite the fact that each of the orchards was selected because of past history of aphid infestations. Also, during the six years many other orchards were visited and in practically none of these was damage by the rosy aphis of any commercial importance. Based upon the above records, the conclusion must be that *Anuraphis roseus* is not a serious commercial problem to the apple growers of Ohio. This has already been stated in the Popular Section of this bulletin.

There is always, of course, the possibility that this species may occur in serious numbers at periods in a long time cycle and that this work has been done between two such periods. However, due to the high biotic potential possessed by this species we do not believe this probable. Cycles in which injurious outbreaks occur at short intervals are characteristic of insects possessing a high biotic potential. By far the greater part of the data that were

secured in the years of infestation concerns *Rhopalosiphum prunifoliae*. This species differs in many ways from *Anuraphis roseus* but it is thought that in early spraying it would be harder to reduce to small numbers than *roseus*. This is because the eggs of *prunifoliae* are so much more abundant (exceeding those of *roseus* in most instances at least 100 to 1) and are also scattered so much more generally over the tree, almost every terminal and spur carrying them. Therefore, a very thoro job of spraying must be done in order to secure a minimum infestation of *prunifoliae*.

In connection with dormant and delayed dormant spraying against *Anuraphis roseus* and *Rhopalosiphum prunifoliae* the question at once arises as to what possible effect these sprays will have on *Aphis pomi*. Data have been taken on this point in all the experiments where green apple aphis followed in outbreak proportions. In only one out of fourteen cases was there any appreciable control and that was a case of infestation occurring in early June. In all other instances *Aphis pomi* over-spread the sprayed plots at exactly the same rate as it covered the untreated checks. If the sources of green aphis infestation were to be found only in the orchard that is to be treated then undoubtedly there would be a measure of control but since the infestation comes from migrants which frequently fly from considerable distances, the delayed dormant sprays are not to be relied upon. Where the eggs of *Aphis pomi* are abundant upon certain trees in the orchard these should be treated, particularly if the orchard has suffered from green aphis attacks in the immediate past. In general, however, it may be said that the dormant and delayed dormant sprays have very little effect on infestations of *Aphis pomi* and that they cannot be recommended for controlling this insect.

SUMMER SPRAYING AGAINST *APHIS POMI*

According to the summarization of the last section the use of any spray material in the dormant or delayed dormant period, applied with the idea of controlling the green aphis, is almost sure to meet with failure. Therefore, we must abandon this method and turn to the possibilities of controlling the insect by summer spraying or spraying after it appears on the trees in numbers. In determining what materials should be used in field trials a large number of laboratory tests were conducted which can not be given here in detail. Nicotine sulphate was the material to which most attention was given. It was used alone, in combination with all the common fungicides, with various types of soap, and with many

brands of oil sprays both miscible oils and oil emulsions. Miscible oils and oil emulsions were also used alone. Other materials that were tried were Derrisol, Coccotine, and certain pyrethrum extracts. The result of these trials was the conclusion that nicotine, 1-1600 or stronger, combined with ¾% miscible oil or 1% oil emulsion was the most efficient aphicide that had been found.

Field trials of the materials on small trees were then conducted and the results of one such trial are given in Table 20.

TABLE 20.—Summer Sprays Against *Aphis pomi*

Material	Dilution	Per cent killed
"Volck" oil emulsion	2%	99.0
"Volck" Nicotine sulphate	1% 1-1600	99.5
"Volck" Nicotine sulphate	½% 1-1600	98.5
Check-no spray		apparently all living

This table shows the effectiveness of "Volck" when used alone and at lower percentages with nicotine sulphate. The materials were applied with care and thoroness to three-year-old trees of the King David variety and their effectiveness can not be doubted. There was no injury to foliage. Further tests are shown in Table 21.

TABLE 21.—Summer Spraying Against *Aphis pomi*

Material	Dilution	Per cent killed
Nicotine sulphate	1-1000	90
Nicotine sulphate Rex oil emulsion	1-1600 ¾%	99
Nicotine sulphate Sunoco	1-1600 ½%	98.5
Nicotine sulphate Hydrated lime	1-1600 5 lb.-50 gal.	94
Nicotine sulphate Kayso	1-1600 ¾ lb.-50 gal.	93
Check-no spray		apparently all living

Other tests showed that the engine oil emulsions commonly used during the dormant period could be safely applied to foliage at 1% of the emulsion but at this strength certain miscible oils might burn. However, at ¾% no serious injury with most miscible oils has been noted. Of course it was not possible to test every brand in this manner. Taking the factors of cost, safety to foliage, and

effectiveness into account, it seemed that the conclusions of the laboratory experiment were verified. Volck is safe on foliage and an excellent spreader for nicotine but is rather expensive. While nicotine at 1-1600 has given excellent results in the experimental work it was thought that a greater strength should be used in commercial work to offset mechanical difficulties of application, that is, the greater amount of nicotine fumes secured from more nicotine in the spray, would counteract such factors as lack of coverage and imperfect spraying of the entire tree.

This combination as recommended has been used for the past three years in the orchards of several representative growers of the State and has uniformly given good results if a sufficient amount of spray has been thoroly applied.

At the present time a new oil known as Penetrol is being tried as a spreader for nicotine. Laboratory tests, such as those in Table 22, show that this material is quite effective and enables nicotine to be used at much lower strengths.

TABLE 22.—Nicotine with Penetrol and Other Oils. *Aphis pomi* **on Apple**

	Material	No. aphids	No. dead	Per cent dead
1st test	Check	300	59	19
	Rex oil 1% + Nicotine 1-2000	708	703	99.3
	Penetrol 1% + Nicotine 1-2000	704	702	99.7
2nd test	Check	615	94	15
	Rex oil 1% + Nicotine 1-2000	532	526	99
	Penetrol 1% + Nicotine 1-2000	370	370	100
3rd test	Check	484	191	39
	Rex oil 1% + Nicotine 1-2000	604	601	99.5
	Penetrol 1% + Nicotine 1-2000	194	194	100

Further results show that the Penetrol can be reduced to ½% strength and that nicotine can also be further lowered and good results still be obtained.

In the field four minor tests have been conducted against *Aphis pomi* on apple and spirea. These are detailed in the following table.

In all instances cited the spray was applied with a power sprayer maintaining a pressure of 300 pounds. A spray gun was used and the spraying was thoroughly done. The results indicate

TABLE 23.—Field Tests Against *Aphis pomi* with Nicotine and Penetrol

Material	Date	Host	Temperatures	Aphids sprayed	Per cent killed
Penetrol ½% / Nicotine sulphate 1-4000	6/10	Spirea	58-68° F.	1550	94.7
Penetrol ½% / Nicotine sulphate 1- 800	6/10	Spirea	58-68° F.	820	98.6
Penetrol ½% / Nicotine sulphate 1-4000	6/17	Spirea	75-80° F.	1345	97.7
Penetrol ¾% / Nicotine sulphate 1-1000	6/17	Spirea	75-80° F.	2325	99.4
Rex oil ½% / Nicotine sulphate 1-2000	6/17	Spirea	75-80° F.	993	99.5
Penetrol ½% / Nicotine sulphate 1-4000	6/23	Apple*	80-90° F.	7235	99.8
Penetrol ½% / Nicotine sulphate 1-1000	6/23	Apple	80-90° F.	985	100.0
Penetrol ½% / Nicotine sulphate 1-4000	7/ 9	Cult. Crab apple†	85-95° F.	2725	83.2

*Six-year-old apple trees of average size.
†Large tree with severely curled foliage.

that the higher the temperature, the greater is the mortality of aphids except in cases where the foliage was so severely curled that the spray could not reach them. The tests show that Penetrol and low-strength nicotine have decided promise for use in the field and if a few more tests give equally good results that it may be definitely recommended.

FERTILIZATION, CULTIVATION, AND PRUNING IN RELATION TO *APHIS POMI*

These three factors, all of which are closely connected, play parts of importance in the life economy of the green apple aphis.

1. Fertilization.—In experiments with various fertilizers for apple orchards in sod that are being conducted at Wooster and other points in the State, the check or unfertilized trees have regularly shown a lower rate of infestation than the treated trees. The degree of difference depends largely on the natural fertility. If the soil is very poor the untreated trees will escape almost entirely. A very striking example of this sort was noted by the writer in 1925 at Chardon, Ohio, in the Bingham orchards. Here an extensive experiment with different fertilizer treatments for apple was in progress. All plots of trees were in sod and were uniform as to variety, size of tree, and location. In the center of the treated plots was one unfertilized check plot consisting of twelve trees. This caused a remarkable difference in infestation.

Whereas all the fertilized trees were heavily infested with almost every terminal carrying a thriving colony of *pomi*, the check trees were almost free from aphids and the great majority of the short terminals were unpopulated. This series of plots was also examined in 1927 and again the same condition existed. However, if the soil is naturally fertile and trees are making good growth without the aid of fertilizers, there will be only a small amount of difference in infestation existing between the treated and untreated trees.

2. **Cultivation.**—This practice always tends to promote growth and in this way is favorable to *pomi*. In a series of cultivated plots that were receiving different fertilizers it has been frequently noted that the unfertilized trees were infested to a much greater extent than if the series had been in sod. Likewise, it has been noted that where cultivated and sod orchards were adjacent to each other that the cultivated area always carried the greater aphid population particularly if both orchards were unfertilized.

Fig. 16.—Tree with large amount of water-sprout growth. Such trees are excellent breeding places for green apple aphis.

3. **Pruning.**—The fact that water sprouts and vigorously growing terminals furnish the most favorable food for *Aphis pomi* suggests at once that if there was some method of eliminating this type of growth from the tree the problem of control would be almost solved. Not only do water sprouts and growing terminals furnish food throughout the growing season but they also furnish the place of overwintering for the eggs of the species.

In 1925 a study was made of the green apple aphis infestation occurring in a large block of trees belonging to the Melrose Orchard

Co. of Wooster, Ohio. The varieties consisted of equal numbers of Delicious, Stayman, and King David; all were of the same age and had received uniform fertilizer and spray treatments. The only thing in which the trees differed was type of growth. Some were very bushy with the interior of the tree filled with water sprouts (thick), others were almost free from water sprouts (open), while others represented an intermediate condition (medium thick). After some thought it was decided to use the above classification in a study of the infestation of *pomi*. The infestations as occurring on each tree were then grouped as follows:

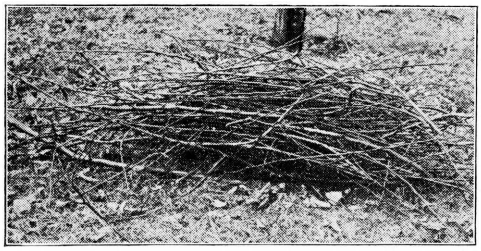

Fig. 17.—A bundle of prunings taken from an over pruned tree. The large amount of water sprout growth produced by such a tree is very favorable to green aphis infestation.

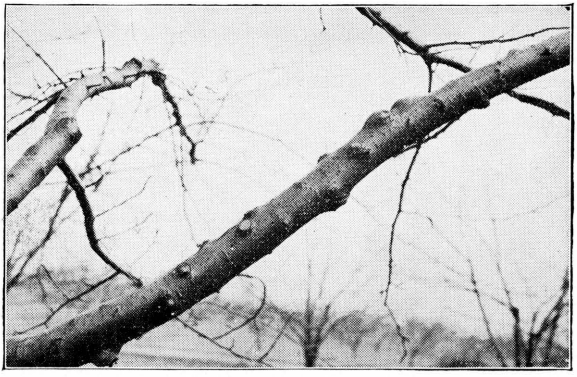

Fig. 18.—Scaffold branch with many pruning scars. A branch so pruned will produce numerous water sprouts, very favorable for green aphis feeding.

Light infestation.—A condition in which it is not necessary to apply any control.

Medium infestation.—Most of the terminals on the trees were infested and a few of the leaves showed the growth of the black fungus.

Heavy infestation.—Over half of the leaves and fruit were blackened by the fungus.

Very heavy infestation.—All leaves and fruit were blackened by the fungus.

Each tree in the block was then studied and classified as to its condition of growth and also as to the type of infestation. The result of this double classification is shown in Table 24.

TABLE 24.—Correlation Table. Growth Condition With Infestation

Degree of aphis infestation	Growth condition of tree		
	Thick	Medium thick	Open
Light infestation	37	64	70
Medium infestation	27	60	11
Heavy infestation	85	4	1
Very heavy infestation	26	3	1

When Table 24 is treated as a correlation table the significant correlation coefficient of .5732 is found and from it odds of over 3,333,333 to 1 may be figured. The common sense observation that there is a definite correlation between growth and infestation is thus firmly supported by mathematical analysis.

A few weeks later in the same season an additional study of the same nature was made in orchards at Chardon, Ohio. The results obtained there are given in Table 25.

TABLE 25.—Correlation Table. Growth Condition With Infestation

Degree of aphis infestation	Growth condition of tree		
	Thick	Medium thick	Open
Light infestation	1	29	42
Medium infestation	9	54	17
Heavy infestation	19	33	6
Very heavy infestation	14	12	3

The data above fully support those of Table 24. A statistical study of Table 25 gives a correlation coefficient of .4498 with odds of over 3,333,333 to 1 that the data are significant.

The above data show conclusively the relation between succulent growth and severe infestations. Furthermore, based on observations extending over five years, the statement can be safely made that similar data may be collected in any orchard where such types of growth exist and where an infestation of *Aphis pomi* is present.

From the standpoint of green aphis control, pruning should be used in such a manner as to remove water-sprout growth from the tree and also to discourage future growth of a similar nature. This

latter idea involves considerable difficulties from the horticultural standpoint but should be given careful consideration in orchards where green aphis is a problem. As fertilization and cultivation are so closely connected with growth and therefore with the type and amount of pruning that must be done, they also assume an important part in the control problem. There is no doubt that since the use of nitrogenous fertilizers became common in commercial orchards the green aphis problem has increased in import-

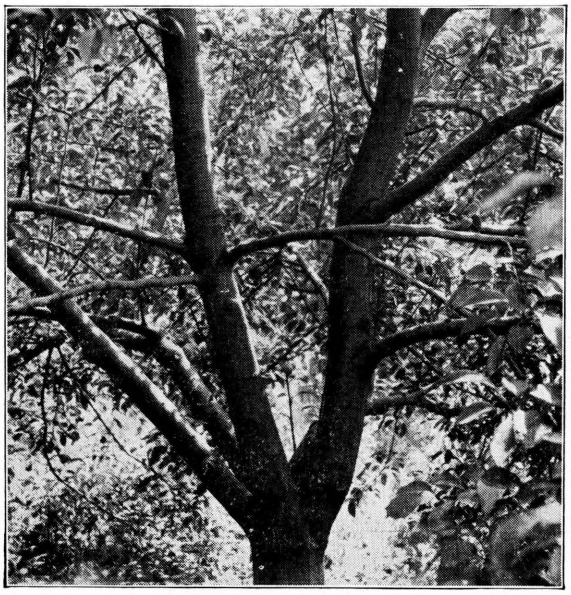

Fig. 19.—An open centered tree. During a year of heavy infestation by the green apple aphis this tree was not injured

ance. Since fertilizers must be used in order to secure profitable yields its discontinuance or curtailment can not be recommended. However, it is thought that further research may yield results of interest in this field. In general it may also be said that the past 15 years have marked a period of much better general care of commercial orchards. These improved practices, including pruning, fertilization, mulching, and cultivation have all favored *Aphis pomi* in that they all tend to improve the amount and quality of growth that the trees make.

Fig. 20.—A tree with abundant water-sprout growth in the center. Such growth frequently supports colonies of green aphis even in years of light infestation

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